THE UNIVERSITY OF CALGARY

The Use of Geographic Information Systems for the Preparation of Environmental Impact Assessments

by

Michael John Lyzaniwski

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- Canadian (French) 0355
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- General 0310
- Accounting 0272
- Banking 0770
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- General 0501
- Agricultural 0503
- Commerce-Business 0505
- Finance 0508
- History 0509
- Labor 0510
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Geography 0366
Gerontology 0351
History
- General 0578
- Ancient 0579
- Medieval 0581
- Modern 0582
- Black 0328
- African 0331
- Asia, Australia and Oceania 0332
- Canadian 0334
- European 0335
- Latin American 0336
- Middle Eastern 0333
- United States 0337

History of Science 0585
Law 0398
Political Science
- General 0615
- International Law and Relations 0616
- Public Administration 0617

Recreation 0814
Social Work 0452
Sociology
- General 0626
- Criminology and Penology 0627
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- Industrial and Labor Relations 0629
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- Social Structure and Development 0700
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Women's Studies 0453

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- General 0473
- Agronomy 0285
- Animal Culture and Nutrition 0475
- Animal Pathology 0476
- Food Science and Technology 0359
- Forestry and Wildlife 0478
- Plant Culture 0479
- Plant Pathology 0480
- Plant Physiology 0817
- Range Management 0777
- Wood Technology 0746

Biology
- General 0306
- Anatomy 0287
- Biostatistics 0308
- Botany 0309
- Cell 0379
- Ecology 0329
- Entomology 0353
- Genetics 0369
- Limnology 0793
- Microbiology 0410
- Molecular 0307
- Neuroscience 0317
- Oceanography 0416
- Physiology 0433
- Radiation 0821
- Veterinary Science 0778
- Zoology 0472

Biophysics
- General 0786
- Medical 0760

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Physical Geography 0368
Physical Oceanography 0415

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- Audiology 0300
- Chemotherapy 0992
- Dentistry 0567
- Education 0350
- Hospital Management 0769
- Human Development 0758
- Immunology 0982
- Medicine and Surgery 0564
- Mental Health 0347
- Nursing 0569
- Nutrition 0570
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- Occupational Health and Therapy 0354
- Ophthalmology 0381
- Pathology 0571
- Pharmacology 0419
- Pharmacy 0572
- Physical Therapy 0382
- Public Health 0573
- Radiology 0574
- Recreation 0575
- Speech Pathology 0460
- Toxicology 0383

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- Inorganic 0488
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- Polymer 0495
- Radiation 0754

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Physics
- General 0605
- Acoustics 0986
- Astronomy and Astrophysics 0606
- Atmospheric Science 0608
- Atomic 0748
- Electronics and Electricity 0607
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- Fluid and Plasma 0759
- Molecular 0609
- Nuclear 0610
- Optics 0752
- Radiation 0756
- Solid State 0611

Statistics 0463

Applied Sciences
Applied Mechanics 0346
Computer Science 0984
Engineering
- General 0537
- Aerospace 0538
- Agricultural 0539
- Automotive 0540
- Biomedical 0541
- Chemical 0542
- Civil 0543
- Electronics and Electrical 0544
- Heat and Thermodynamics 0348
- Hydraulic 0545
- Industrial 0546
- Marine 0547
- Materials Science 0794
- Mechanical 0548
- Metallurgy 0743
- Mining 0551
- Nuclear 0552
- Packaging 0549
- Petroleum 0765
- Sanitary and Municipal 0554
- System Science 0790

Geotechnology 0428
Operations Research 0796
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General 0621
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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled, "The Use of Geographic Information Systems for the Preparation of Environmental Impact Assessments" submitted by Michael John Lyzaniwski in partial fulfillment of the requirements for the degree of Master of Engineering.

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ABSTRACT

This study assesses the use of Geographic Information Systems (GIS) in preparing Environmental Impact Assessments (EIA). The literature, interview and survey of experts involved in the environmental impact assessment process, indicate that there is a move towards increasing the capabilities and the accountability of the environmental expert in predicting project impacts on the environment, and in planning for their occurrence. There is a need to focus on the significant impacts and to improve prediction capability. In the geographic information system area, the systems are becoming more capable, and user friendly. Specific areas of GIS strength are in visual display of output, spatial data organization and manipulation, and modeling. The study concluded that GIS could be used on EIA problem areas and activities that are priority activities in EIA preparation.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

GLOSSARY

Topology (Spooner, p. 75, 1989): "focuses on the connectivity and contiguity within and between figures". The map should convey the interrelationships of the data. Features and the associations between features are conveyed. The topological relations should be set upon digitization.

Anthropocentric (Oxford Dictionary, 1989): "regarding man as the central fact of the universe to which all surrounding facts have reference", Oxford English Dictionary, 2nd ed., 1989.

Raster (Star & Estes, 1990): a cellular organization of the spatial data that is organized in cell arrays or a grid. The cells can be square and the distance between cells constant in both coordinates.

There are limitations to this technique:

- there is a finite limit to specify location, you are in one cell or another, there is nothing in between.
- the cell might represent an average value for an attribute over the entire range of the area covered by the cell.
- cell size is important and based on the elements that are being analyzed. A rule of thumb is to use a raster cell half the size of the smallest feature you wish to record.

Digital Elevation Models (Burroughs, 1986): continually varying surface, displayed with isolines.

Indicators (Liverman, 1988): an organism that is particularly sensitive to the environmental stressor of interest, an indicator should have the following characteristics:

a) temporally sensitive,
b) sensitive to distributions over space and among social groups,
c) predictive,
d) referenced to a threshold level,
e) free from bias,
f) should indicate the costs of reversing/controlling changes,
g) data should be easy to collect.

Phenomenological building blocks: a GIS has basic topological concepts or elements: a point, line, and area that are used to create a map.

Sustainable Development: development that will "ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs." (Rodger, p.i, 1990.

CHAPTER ONE - INTRODUCTION

Preliminary project planning of most industrial development capital projects requires an assessment of the impact of the development upon the environment. Although the extent and complexity of the project may vary, this assessment will take place for any project; from a small church reconstruction, to the mining of oil sands.

There is a great deal of integration of information that is required in an environmental analysis. At the conceptual level when the project manager is planning the project there is a requirement to identify the environmental issues that could disturb, delay, enhance or disrupt the project's progression to completion. In the environmental arena there is a need to identify these issues and then integrate them into engineering design within the context or baseline provided by the environment. It is becoming very important for the project manager to follow the principle of sustainable development. This principle is inherent in the North American regulatory process. It is a banner of the public participation process many projects are subject to. It is also an area of academic research. The objective is to modify engineering to take the environment into account; designing to minimize environmental degradation.

With the increasing need to take environmental factors into account, even at an early stage, the level of detail the project management team needs to be aware of begins to increase. Successful initiation of the project requires substantial planning and environmental impact assessment of the potential outcomes of the decisions. Potentially huge amounts of data could be processed to portray accurately the environment into which the industrial development will be placed. Data is also used to portray the actual industrial development or its system of activities and by-products that will affect the environment. The difficulty arises when the project management team tries to analyze the integrated data and simulate the impact of changes resulting from the integration. These alterations ideally have to be readily incorporated into a central data base to reflect the impact of the development and the analysis of these results.

Potentially the project management team can use a Geographic Information System (GIS) to help them analyze the environmental impacts. This is a computer system that contains spatially referenced data describing a geographic area. In very simple terms, this is a digital map with an expanded legend. The expanded legend contains the ability or functions to enable in depth information retrieval about a particular geographic location or feature. It has the ability to analyze the information and to describe it in a variety of forms. It can, for instance, calculate distances between locations, or calculate the volume of a specific soil layer in an area. As well, it has the capability to be programmed to perform its own analytical procedures, customizing a particular project team's analysis needs into an analytical tool.

Currently there are dozens of GIS's on a variety of platforms including UNIX workstations, PC-DOS, and Macintosh. The main areas of research in the GIS field are data acquisition, data interpretation and analysis. The process of attaining digital information files and manipulating these computer files in such a way as to be usable by the myriad of GIS's available today is a key issue. Though the GIS was not initially designed to support or assist in the preparation and management of environmental impact assessments, there has been development work done by Government departments of the environment and various resource based companies. They have used a GIS as the base from which to begin development of a system to help create a data base to be used in environmental impact assessments, and to better plan for the effects of an industrial development on an environment.

Specifically, this thesis is about streamlining and potentially improving the Environmental Impact Assessment process by using a Geographic Information System. In many projects, especially those industrial developments that are in relatively untouched wilderness areas, there is a need to assess the impact of the industrial development on that virgin area. Such an Environmental Impact Assessment (EIA) is the precursor to regulatory approval of many industrial developments in North America. The industrial development will have a wide range of impacts on an area. The Project Manager (PM) of the development must be able to ascertain the environmental impacts that will be potentially disruptive to the project. The stakeholders in the project will also be interested in knowing what the impact is. They will then want to know how to mitigate the impact by altering the design of the project. Though the PM is not the environmental expert in the geographic area of the project, he or she must be able to prioritize the potential environmental disruptions the project will cause. There are many groups that express concerns over the environment. They all have various levels of political standing and validity. There is a need to determine which issues are real, and to try to quantify and understand them.

This paper overviews the literature, explains the preparation of EIA's, and describes a plan of action for the research of the EIA/GIS link. The conclusion reached is a recommendation as to what GIS attributes are practical and useful in preparing an EIA.

It is expected that the PM team and the stakeholders will want to model the environment and perform what-if analyses on the model. This exercise will help bring into focus the environmental impacts of continual industrial development operations and would help the PM team visualize any abandonment and reclamation plans.

1.1. Review of Literature

1.1.1 EIA

1.1.1.1 Historical EIA Development

Early eminent scholars had initial forewarnings regarding environmental degradation that were echoed by Malthus (Heilbroner, 1986, pp. 75-104) in the 18th century. In time there was enough of a public awareness that the government took steps to administrate the process. The EIA process that is familiar to many people today, started in the 1950's in North America, Japan and Europe (Henry, 1989). The approach at that time, and one that is still prevalent, was anthropocentric. There was however no overall coordination of the government regulatory boards that approved and licensed the facilities being built. In the 1960's and 1970's with a growing environmental awareness by special interest groups, the governments of the day recognized the coordination problem and that the participation of special interest groups had validity in the planning process of major projects. The result was legislation that tried to comprehensively deal with the environment, and include public input. In the US the NEPA or National Environmental Policy Act, and in Canada the EARP or Environmental Assessment Review Process, governed the use of federal lands and properties, limiting the impact a development might have on those properties. Since that time EIA's have not only become concerned with the physical properties of a site but also the biological, ecological, and socio-economic characteristics.

1.1.1.2 EIA Content

The methodologies referred to in the literature, indicate that although there is some uniqueness to the preparation of the EIA, there are overall encompassing steps and investigatory areas that are common to all developments (Holling, p. 3, 1978).

One of the steps taken in an EIA preparation is to determine whether a project is governed by a particular set of regulations and legislative acts. This could subject the project to the scrutiny of a public inquiry with its resulting public hearings. Another step is to determine who the participants in the process are. Further to that, the content of the EIA should include the following (Henry et al, p. 635, 1989):

1. A description of the proposed action.
2. An estimate of the nature and magnitude of the environmental effects.
3. A listing of relevant human concerns.
4. A criteria list describing how to rate the significance of the environmental impacts.
5. An estimate of the significance of the proposed action.
6. A recommendation of action regarding the project.
7. A monitoring program recommendation.

The first two content items require explanation. The first content item should include a description of the project's construction, its operations, shutdown, abandonment and site reclamation; i.e. the complete project life cycle. The second item is of enormous importance. It should include the three areas of physical, biological, and socio-economic impacts. The biologic and socio-economic impacts are very difficult to quantify and, in some cases, identify. According to Henry (p. 639, 1989) "...living organisms are adaptive and contain great genetic variability, so that their reactions to multiple environmental stresses are not always predictable." This complicates the EIA process and indicates a need to integrate a great variety of information and data in order to investigate and assess the impacts of the project on the environment. Such integration, especially in the biological or ecological areas, help identify indirect, and perhaps, long term impacts that are not immediately apparent, and perhaps not immediately recognizable as detrimentally effecting humans. Although the third item is important, the sociological human concerns are not dealt with fully in this work, being beyond its scope. The rest of the items are dealt with in the second chapter of the thesis.

The next area of importance in performing an EIA is to define the project in terms of time, area or space, and the factors to be taken into account. The time frame includes the construction and operations at the site, and future reclamation of the site. The space frame encompasses the geographic area that would reasonably be affected by the project in question. The factors to be taken into account are a scoping list of issues that describe the relevant and important facts that are of concern to the EIA participants.

1.1.2 GIS

1.1.2.1 Description of GIS

According to Cowen (1988), "a GIS is best defined as a decision support system involving the integration of spatially referenced data in a problem solving environment." He goes on to say that the integration is an important part of the system, and is particularly useful in bridging data and informational gaps between "various sciences, physical as well as social".

According to Burrough (1986) a GIS is special in terms of data handling because it requires: a coordinate system to describe position, and a system of phenomenological building blocks of different scales to describe the geographic structures. A GIS has basic topological concepts or elements: a point, line, and area that are used to create a map. As well the data base supporting and storing the information that would help create a map are usually organized in hierarchical, network or relational structures. The representation of the map by the computer is done in two forms. Explicit or raster form is a set of points that represent every point on a map. They are akin to the array of picture elements on a television screen. Implicit or vector format is a set of lines and angles representing line entities such as a road.

1.1.2.2 Evaluating GIS

The literature describes methods of evaluating GIS, the features to evaluate and the performance to check for. Guptill (1989) describes how to perform a User Requirements Analysis (URA) for a GIS implementation. The GIS Source Book of 1989 describes some of the basic features to look for in a GIS. These include basic system capabilities, data manipulations, and analysis functions. These reports generally establish a procedure by which to investigate and analyze the various GIS's available.

1.2 The Problem

The problem for the PM is a morass of environmental and related data, information, issues, and opinions that must be sifted, analyzed, and synthesized. The PM must have a way to sort through, identify, and classify the various important issues that deal with the environment. (How does the PM and the environmental external issue expert store and assess the information that helps them determine the impact their project will have on the environment?) Ideally the PM should be able to take the industrial development and overlay it onto the existing environmental base. The existing environmental base is the air, land, and water map that describes the ecosystem and geographic area and its attributes (i.e. the constituent geographic, biological and physical/chemical characteristics). The industrial development will disrupt this environmental base to some degree. Some parts will be affected substantially, while others will be relatively untouched as far as can presently be measured. The environmental expert assesses the range of impacts and works with the PM and the engineering team to design the least disruptive, or most easily mitigated and/or reclaimable industrial development within the constraints of economic feasibility. Figure 1.1 below describes the process.

Theoretically this process can be split into two distinct parts[1]. The first part involves the gathering and storage of the environmental information. The second part is the processing and integration of the information to analyze and assess the impact of the development on the environment. The PM uses engineers who will design the industrial development, and environmental experts who will assess the environmental base. These experts will have to store the information and designs that they develop and then relate the two disparate parts: man's design and mother nature's environment. The environmental expert will have to use this information and assess the impact of the industrial development on the environment. This analysis will prepare the PM for the next step of assessing

[1]Goodman R.H., Private Communications, Esso Resources Canada Limited, Calgary, Canada, 1991,1992.
and
Roger, E.E.; The Design of Systems for Environmental Information, with Emphasis on Third World Applications; Faculty of Environmental Design, University of Calgary, Canada; 1990; Graduate Studies Thesis.

alternative designs and their respective EIA's in the achievement of the goal of the optimum design in regards to sustainable development[2].

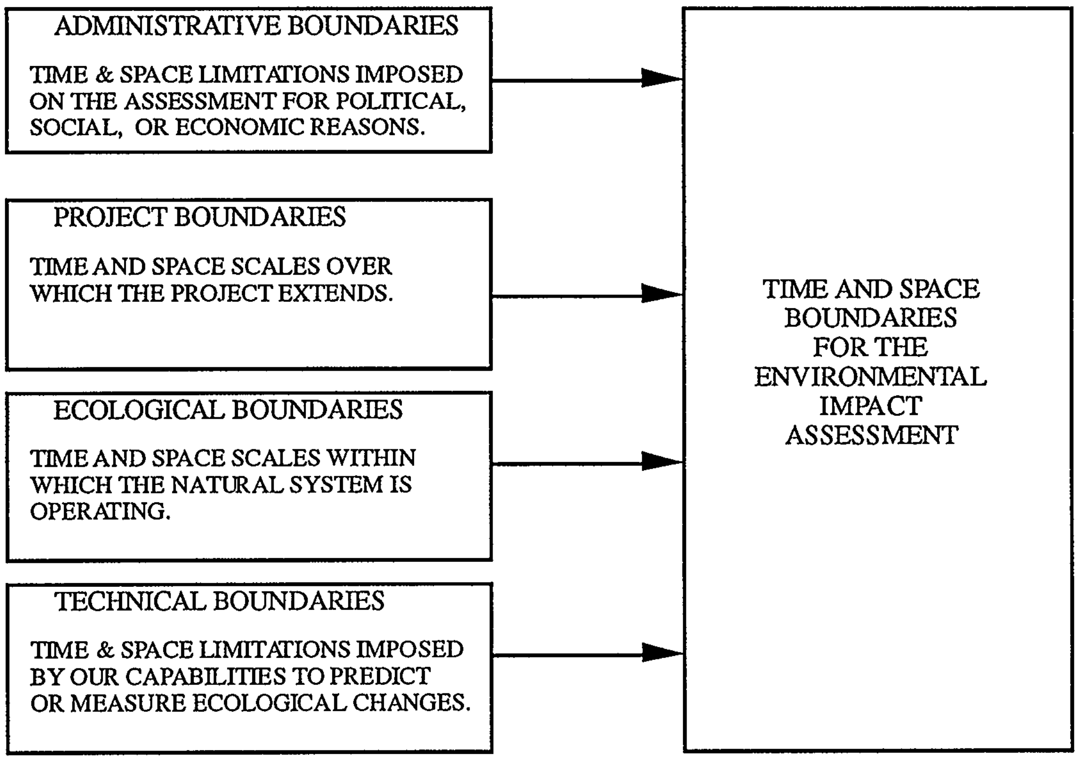

Figure 1.1 Time And Space Boundaries In Environmental Impact Assessment (Beanlands & Duinker, 1983)

1.3. The Hypothesis

The problem of storing, processing, and integrating the environmental information can be solved with the use of a Geographic Information System (GIS). This system has the capability to geographically or spatially reference various attribute data that describes a physical location. A GIS is "a computer-based system that links geographical locations with information about those locations"[3]. For instance, it would contain data base information that would be spatially referenced to the land using a land survey reference system. This visual reference system would be used to locate informational sets of data

[2]For a definition of 'sustainable development' see Roger, E.E. and for further information see IUCN, 1980 Section 10

[3]According to Nucor Computing Resources Inc. Training Course Manual; P.O. Box 135201, Kanata, Ontario, Canada, K2K 1X6.

that describe pictorially and literally information such as the wildlife habitats, forestry ranges, waterways, wind patterns, soil compositions, road systems, and ground water flow patterns. The system could also contain datasets and data bases that describe or model the industrial development that would be in the area. The environmental expert would use this tool to project the effects of the industrial development on the environment. The expert would predict the effects of the development on the various datasets that model the environmental sectors (i.e. air, land, water) and integrate the effects of the industrial development on an environmental sector, with other environmental sectors. This is done to predict the cumulative effects of the development. For example, a dam on a stream would have the direct effect of drying up the stream bed downstream of the dam. The indirect effect would be the displacement of any wildlife that resided or depended on the stream for nourishment. These effects would be assessed and compared with different models that portray the industrial development design alternatives.

A study done by Esso Canada Resources Limited tested this hypothesis. The study used a GIS to collect and store information describing an oilsands development. The oilsands development was a strip mining and pre-processing operation. The GIS contained data bases and images that described the soils, vegetation, forests, wildlife, and geography or contour elevations. A micro-computer based GIS called NUCOR[4] was used. Although the use of the system was favorably received, there were some problems with that particular system, specifically regarding:

- data collection and fast input of data into the system,
- analysis capabilities as compared with analysis requirements,
- output requirements of the EIA experts,
- training requirements,
- time required to train operators of the system (Case, 1991).

The hypothesis can be tested by assessing what the PM and the EIA expert would require as a decision support system for the external issues of the environment to be precisely evaluated in the planning of an industrial development.

This literature search of the EIA and GIS fields resulted in a priority item list being completed in order to interview and survey: environmental consultants, software

[4]Nucor Computing Resources Inc.; P.O. Box 135201, Kanata, Ontario, Canada, K2K 1X6.

developers, project proponents, academics, and governmental bureaucracies that regulate and champion the public's interest. The results of this investigation indicated which EIA functions and procedures could be streamlined using a GIS.

1.3.1 Limitations of the study

The EIA investigation was only concerned with non-socio-economic data. It dealt with the North American GIS products and North American regulatory concerns. Little research into regulations was done. It should be noted that the Canadian and Albertan regulations are being changed.

1.4. Research Design

Figure 1.2 describes the research project.

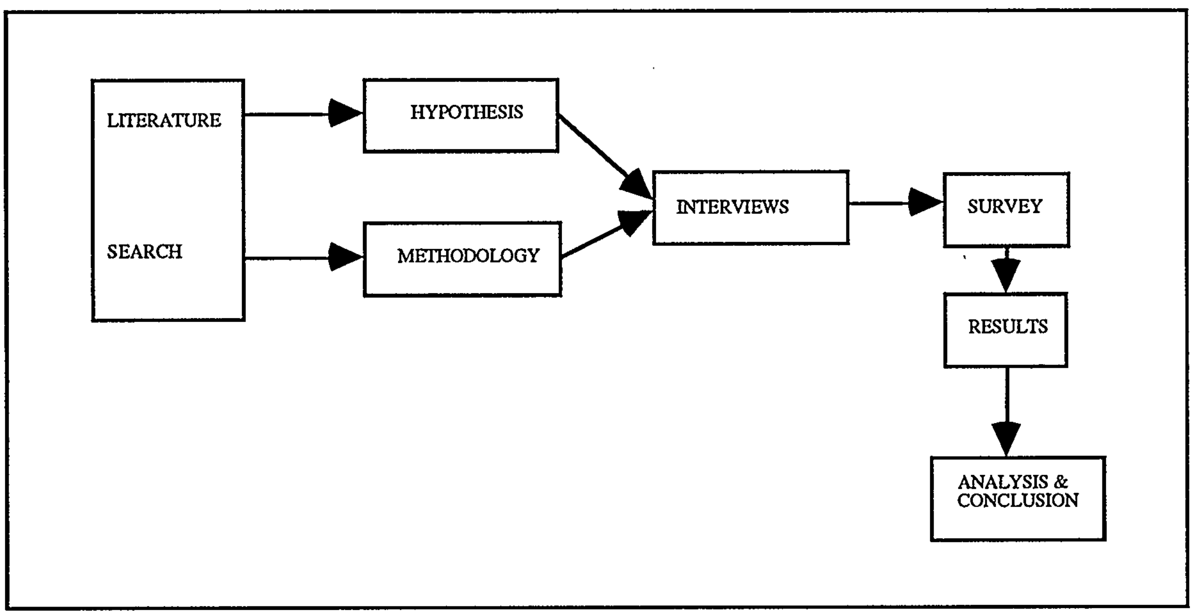

Figure 1.2 Research Design Diagram

1.4.1 General Method

The general methodology used for this thesis was to theoretically analyze and compare two disparate technical specialties to evaluate the potential synthesis and integration (synthegration) of the specialties. A Kantian analysis (Linstone & Turroff, 1975) was used as the general theoretical guide in developing the survey and interviews.

1.4.2 Research population or sample

The experts and personnel consulted and used as advisors came from the Energy Resources Conservation Board, Natural Resources Conservation Board, The University of Calgary, Alberta Environment, various environmental, resource development, and GIS companies, as well as the Environmental Protection Agency in the United States.

1.4.3 Treatment of Data

The data that was collected referred to the GIS capabilities and the checklist of issues that a typical EIA must address. The hypothesis test involved the evaluation of the GIS capabilities against the EIA requirements. This determined which of the features of the GIS can best be implemented and used to better prepare, organize and streamline the EIA process.

CHAPTER TWO - ENVIRONMENTAL IMPACT ASSESSMENT

Preamble

This chapter is specifically oriented towards the explanation of the EIA process. There are certain contradictions in the definitions and the semantics used to describe the process and some of the early authors are somewhat inclined to favour a comprehensive full ecosystem investigation of the environment as an accepted way of preparing an EIA. However the current theme (especially evident in the 1992 works of Kennedy & Ross, as well as Holling, 1978), as developed over the past twenty years, brings forward the idea that the EIA process should be systemetized as much as possible.

This chapter is structured to first define the terms and the philosophy behind the EIA process, and to provide a brief description of some of the current EIA practices and government legislation in North America. Important topics, EIA evaluations and administrative concerns, are discussed to indicate the importance of planning. Next the environmental elements and investigatory approaches are listed. The team preparing the EIA is very important. The personnel required in such a team must be integrated in their work. The results of their effort leads to the evaluation of the gathered information for the creation of alternatives. This is the deliverable to the decision makers. One of the more important decision areas to consider is the risk factors associated with the various alternatives. The most crucial area that must be dealt with is the communication of the decision findings and conclusions of the process to the public. This is essential and must be done flawlessly. A brief explanation of the future study areas completes this chapter.

2.1. Definitions:

As mentioned in Chapter One, the project manager of any development project will be drawn further into a comprehensive environmental planning process (Beanlands & Duinker, 1983). If there is a need to be involved more in the conceptual planning stage of the development, a familiarity with the EIA process is a must. The EIA is not a block to development but a strategic way of planning a development over its operational life. The cost of using EIA in the planning process is usually less than the cost of remedial action (Weston, 1992).

As comprehensive environmental planning influences more projects, the underlying principle behind this planning, sustainable development, must be understood. Sustainable development is a continuity in meeting human needs into the future (Rodger, 1990). In order to achieve this goal, there is a need to alter the planning process for projects. This alteration takes the form of an environmental impact assessment. An environmental impact assessment has been variously defined:

> "...*environmental impact assessment* (EIA) is an activity designed to identify and predict the impact on the biogeophysical environment and on man's health and well being of legislative proposals, policies, programmes, projects, and operational procedures, and to interpret and communicate information about the impacts." (Munn, p. xiii, 1979).

> "The definition of an impact is the effect of a human induced action on an ecosystem. .....Assessment is the analysis and evaluation of impacts on a system. Analysis is the objective task of taking measurements of baselines, identifying actions, predicting changes to the baseline. Evaluation is the subjective task of setting values." (Westman, p. 5, 1985).

> EIA is the:
> "documentation of an environmental analysis, which includes identification, interpretation, prediction, and mitigation of impacts caused by a proposed action or project."

Environmental impact statement or EIS is:

> "the documentation of an environmental analysis of a project or action with a potential for environmental impacts which are either significant or highly controversial."

Proper assessments should determine if a project will cause a significant impact, and if there should be controversy. Assessments should continually build an environmental awareness and disclose the consequences of a proposed action. EIA should be done concurrently with engineering design and economic studies (Jain et al, p. 18, 1977).

Canter (1977) defines EIA in two parts:

- The preparation of an environmental inventory or an auditing report of the effected environment. This is a complete description of the environment being perturbed.
- An attempt to evaluate the consequences of a proposed action. In order to adequately plan an assessment, an interdisciplinary, systemized, and reproducible approach must be taken. This assessment will result in a prediction of the change, a determination of the magnitude, and an appreciation of the importance of the impact.

The Alberta Government (Bill 23, 1992) lists the contents of what should be part of the EIA report, or at least the minimum that is acceptable for the report. The report should contain:

- a description of the activity,
- an explanation of the site selection procedure,
- an environmental baseline description,
- a description of the potential positive and negative impacts, including cumulative, regional, temporal, and spatial considerations,
- the significance of these impacts,
- the mitigative plans for these impacts,
- human health issues,
- an alternative examination,
- impact and mitigation monitoring plans,
- emergency contingency plans,
- waste minimization and recycling plans,
- a public consultation plan,
- pollution minimization plans.

The government can expand the scope, and target the focus of the analysis and reporting process to take into account various issues that it feels are of timely interest to itself, the public, and/or the environment.

The undercurrent theme beneath these definitions is that of sustainable development. Projects professing to be developmentally sustainable demand a long term focus. These are projects that will themselves spawn, nourish, and grow spin off projects. This scenario, one that has perturbations beyond the immediate progress report, requires the paradigm shift of looking to the long term in the planning of projects. Not only are project stakeholders concerned with the immediate completion of the project, they are also concerned with the effect of the project on all of its direct and indirect environmental interfaces.

The concept of a significant impact requires definition. According to Beanlands and Duinker (p.3, 1983), a significant impact is:

"Within specified time and space boundaries, a significant impact is a predicted or measured change in an environmental attribute which should be considered in project decisions, depending on the reliability and accuracy of the prediction and the magnitude of the change."

In the design of an EIA, Beanlands and Duinker (1983) describe an entire project as being viewed by scientists as one big experiment (see Figure 2.1). The experiment can be seen as the building of a development in a particular area. The experiment would measure every single perturbation and impact occurring to the environment due to the existence of the development in that environment. This experiment can be a bit unmanageable given the present state of the art in EIA. There are too many perturbations to be measured.

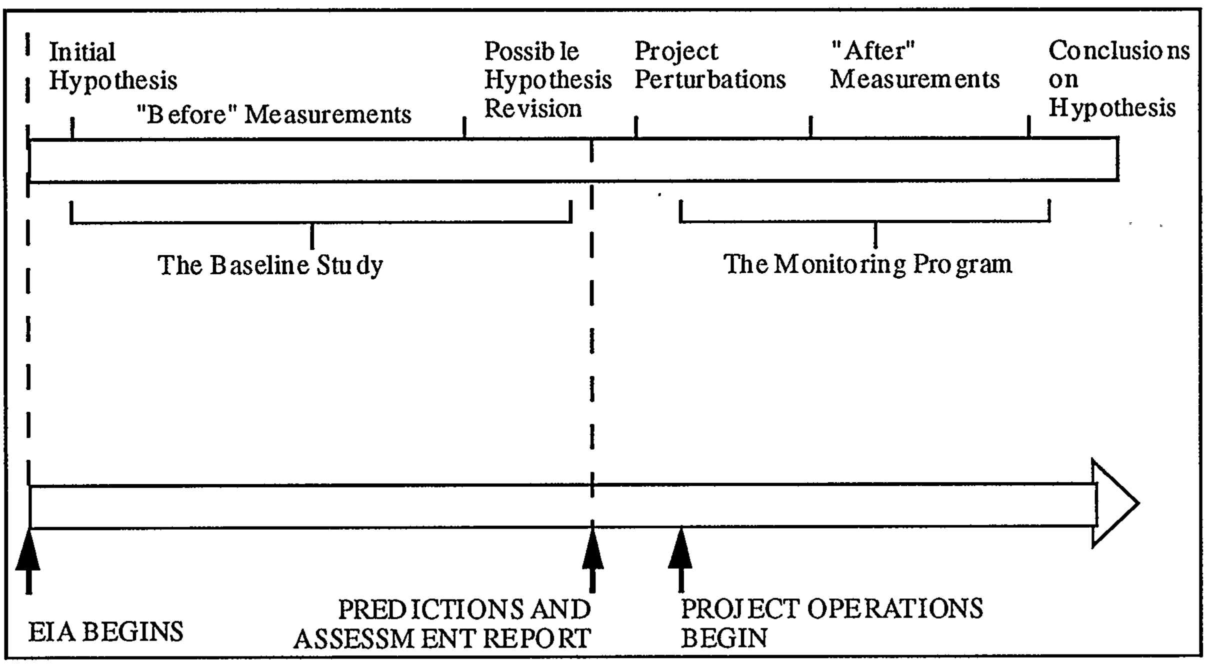

Figure 2.1 An Experimental Context For Studying Project Effects (Beanlands & Duinker 1983)

2.2. Current Practices and Constraints

2.2.1 Introduction

The history of the EIA process is brief, according to Beanlands & Duinker (1983). Formal EIA's have only been prepared since the early 1970's. At that time there was seen to be an inadequate amount of planning, in terms of the impacts that a development might have on the environment. One of the first incidents that helped set the early stage of EIA's was an 8 page study for the proposed 1900 km construction road for the trans-Alaska pipeline. That study, was rejected as being inadequate. Similarily, an eight page engineering design of such a pipeline would be rejected as too superficial. It led to the format of preparing voluminous documents that tried to investigate all biogeophysical impacts and the entire gamut of environmental concerns. The volumes in this type of study grew as gradually more of the baseline ecosystem was documented, along with socioeconomic concerns. Beanlands & Duinker (p. 21, 1983) state that historically the EIA process originated from the public relations forum and:

> "In effect, an ever-broadening range of interests, concerns, and objectives are being 'piggy-backed' onto environmental impact assessment." (Beanlands & Duinker, p.21, 1983).

In the 1970's (Holling pp. 2-5, 1978), the practices of EIA preparation were dictated by a number of myths. The myths describe some of the misconceptions concerning policy design and decisions. Some of the prevalent myths were that:

1. An EIA should consider all possible impacts.
2. Each assessment is unique.
3. 'State of system' ground truthing surveys are required. Masses of data are required for a valid study.
4. Systems analysis can predict impacts.
5. A scientific study contributes to better decision making.
7. Systems analysis allows effective selection of the best alternative.
8. EIA aims to eliminate uncertainty.
9. Planning should be done according to social and economic goals with the environment coming second.

Thorough and exhaustive studies of the environment in an effort to cover all possible impacts and to better support the various predictions made is not the most effective or efficient way to prepare an EIA. Holling stresses that there can be general strategic steps taken in all studies. Every single study does not have a predominant uniqueness due to the geographical area that precludes the use of common initial techniques.

According to MacLaren & Whitney (1985) the history of EIA is built on an administrative basis to achieve administrative goals, not rigorous scientific ones. There have been poorly defined participant roles. Priority has been placed upon social, political, and economic goals with ecology being given a secondary importance. The authors list areas of conflict, some of which are inherent. For instance the ecologist is intrigued with ecosystem function, but the decision maker is concerned with resource and time constraints. A resolution of this conflict is a:

> "greater use of conventional statistical analysis, quasi-experimental approaches, simulation models and a more rigorous approach to the analysis of expert opinion and judgement." (MacLaren & Whitney, p.6, 1985).

Unfortunately, the environmental impact assessments have a limited predictive capability due to the following factors (MacLaren & Whitney, pp. 7-11, 1985):

i) The natural variability in the environment.

ii) EIA professionals usually try to manage the environment to maximize yields. The professionals are used to empirical results, not new predictions.

iii) The focus is on populations, not reasons for environmental variation.

iv) There has been no generic research on EIA.

The guidelines prepared by the government have tried to encompass wider ranges of interests. The result has been a long list of technical review requirements from the various interested parties, both within the government and external to it. This causes a conflict between the demands for quantity of information and the quality of the information. This has led to comprehensive environmental planning.

2.2.2 NEPA/EARP, Bill 23

A discussion of the current EIA practices and history would not be complete without a brief explanation of the American and Canadian regulatory situations. The American National Environmental Protection Act (NEPA) generally has two main sections (Canter, Chapter 1, 1977):

1. National Goals and the integration of various data sources,
2. Applying appropriate weights to qualitatively valued environmental amenities, and a list of basic items that should be addressed. These basic items include:
    - i) Environmental impacts that are indirect, direct, parallel, positive, or negative.
    - ii) Adverse, unavoidable impacts.
    - iii) Alternatives that include no action or development.
    - iv) Local short term uses versus long term productivity of the environment. The issue of trusteeship for future generations.
    - v) Irreversible, irretrievable commitments of resources.

The NEPA (Jain et al, Chapter 2, 1977) has a checklist of eight points to be covered in impact statements.

1. Proposed action description.
2. Relationship of action to existing land use plans.
3. Probable impact on the environment.
4. Alternatives.
5. Unavoidable impacts and their mitigation.
6. Relationship between short term use and long term productivity.
7. Irreversible and irretrievable commitment of resources.
8. An indication of federal policy that could offset adverse effects.

New sections of NEPA dealt with the integration of the various government bodies and their procedures in going through the checklist above. The Environmental Protection Agency (EPA) rates projects in terms of objections to the project and document adequacy as to its assessment of the environment.

Early critics of the NEPA suggested improvements in the areas of reducing levels of generality, dealing with uncertainty and identifying recipients of impacts. Also organizations that carried out EIA's do not have the necessary procedures in place to monitor and evaluate if the recommendations in the EIA were successfully followed in the project. The major adverse effect of the NEPA has been an increase in judicial review.

Beneficially (Jain et al, Chapter 2, 1977) the NEPA has:

- brought national policies in line with environmental concerns,
- provided a system to deal with inter-agency problems,
- included the public in the assessment process,
- initiated an analysis of environmental costs and promoted an awareness of the costs,
- enforced the regulations through the judiciary.

2.2.3 Environmental Assessment and Review Process (EARP)

The Canadian EARP process (Duffy, 1986), is a planning tool, to be used in early project planning stages. The objective of the process is to determine if there are adverse environmental effects caused by projects. The process applies to all projects that have federal government involvement. The EARP process is described fully in Duffy (1986). Progressively they require increasing depth of detail, for the EIA and approval of the project, as problems with the project arise.

The EARP process is being replaced at the time of this writing. Its replacement has been passed and proclamation is expected in June of 1993. From the steps listed by Duffy it can be surmised that as a project progresses and impacts are discovered, more in depth analysis and wide ranging public and government participation occurs. Also the crucial area of the process is in the preparation of the panel of experts. If this is done properly, the completion of the EARP process should theoretically result in a properly planned, low-impact project.

2.2.4 Law & Standards

According to Westman (1985), legislation depends upon project proponents attaining goals and following general guidelines. Legislation has few concrete deterrents or incentives. It is structured to ensure inclusion of the following:

1. A statement of when to conduct assessments,
2. A requirement for preliminary environmental studies,
3. Avoidance of a duplication of effort,
4. A scoping process,
5. A definition of public participation,
6. A recognition of the role courts have in the process,
7. Establishment of decision making bounds due to the environmental findings,
8. A review of international impacts,
9. A provision for post project monitoring,
10. Ensuring completion of a comprehensive scope of analysis to accurately portray the true complexity of the ecological/social interactions,
11. An assessment of the total regional effects of the development.

According to Beanlands & Duinker (p. 33, 1983) there is a pseudo-legal requirement that:

> "Agencies administering assessment procedures will have to establish certain basic scientific requirements that are realistically achievable and set out in a clear and concise manner."

Though legislation has not clearly defined constraints and imposed legal responsibilities for degradation, there has been an attempt in Alberta, through Bill 23, to strengthen this position. The cooperation of many stakeholders in the EIA process is supported in this Bill. The forum created by a participatory process allows the communication of strictly scientific viewpoints to these stakeholders.

2.2.5 Administrative concerns

Administrative concerns are expressed by Kennedy & Ross (1992), and by the Canadian Petroleum Association (CPA) (1991). Since the legislation and guidelines have been quite broad and unfocused, practitioners in the environmental field have attempted to address the legislation with voluminous documents. Compilers of the document are usually experts in one specific area. They are "reluctant to dismiss their areas as unimportant" (Kennedy & Ross, p. 477, 1992). The CPA expressed administrative concerns relating to government regulations. It stated that the government should develop a multi-sectoral process for estimating the cost of environmental protection and sustainable development. It also suggested a cultivation of a process to completely understand international environmental initiatives and their effect on Canada. Especially effects on the business climate, and competitiveness.

Munn (1979) provides a list of the administrative procedures that should be considered when establishing an EIA process. This includes the public participation issue. Administrative procedures are required to support the EIA preparation, and the people directly involved in the preparation. The administrative procedures to consider in designing an EIA preparation are the following:

a) The decision making process should include participants, and a feedback loop needs to be designed.
b) The participants and their activities need integration into the entire project as well as the EIA planning process.
c) A decision must be made as to which group (proponent, independent body, small integrated team) will prepare the EIA.
d) The review of the EIA needs to be planned. The reviewer must be chosen and organized. The scope, budget, team and schedule must be conceptually established.

e) A post-project audit procedure should be planned.
f) Public participation needs to be carefully planned. Respected public representatives need to be members of the decision making team.
g) The publication and dissemination of all procedures and proceedings must occur.

Hite (p.67, 1972) expresses an economic concern that is far reaching in its geographic and political extent.

> "...environmental control regulations can exercise both positive and negative influences on economic development. Moreover, we have seen that environmental control regulations can be manipulated to strengthen the comparative economic advantage of some regions at the expense of other regions.
>
> Protection of environmental amenities, therefore, will require some regions to forego certain types of opportunities for economic growth although it may at the same time increase the opportunities within these regions for other types of economic growth."

The CPA's request for a multi-sectoral approach towards environmental planning, Munn's (1979) requirement of an administrative feedback loop and information dissemination, and Hite's (1972) tradeoff concepts, require special tools to enable these administrative procedures to occur. Computer systems, GIS in particular, could potentially provide a tool to manage multi-sectoral information, provide quick feedback, and evaluate tradeoffs.

EIA Evaluations

According to Beanlands & Duinker (1983), applied ecology provides a basis from which to rank EIA's. The best EIA's will have a conceptual knowledge base firmly rooted in the science of ecology for the project. The ways this is achieved is by:
- Learning from past activities. Similar projects and similar geographic areas react to impacts in similar ways.
- Conceptualizing the project. The term ecological scoping (" social scoping is the establishment of the terms in which impacts should be expressed while ecological scoping represents the terms under which the impacts can be effectively studied." [Beanlands & Duinker, p.5, 1983]) is accurate in describing the terms by which the scope of the project and EIA should be viewed initially. This is required in order to

develop a study strategy. The evaluation of an EIA should see if this type of process is evident and followed by those involved in its preparation.

In evaluating the EIA, Ross (p. 25, 1987), uses the following questions.

1. Does it focus on important impacts?
2. Is it scientifically sound?
3. Can it be easily understood by all who purview it?

These three questions lead to an establishment of a framework for collecting audit evidence in support of 'yes' answers to the questions.

EIA's for construction related projects should ascertain completeness. The significant impacts should be identified and dealt with. An assessment of the validity and accuracy of the information presented should be made. This deals with the scientific soundness principles that Ross mentions. Finally the evaluators should become familiar with the project quickly enabling them to ask substantive questions on it.

These references overwhelmingly support the scientific viewpoint. They are concerned that the EIA study be based on scientific evidence; the hypothesis and proof mindset. This is correct and essential in order to plan the project according to sustainability principles. Practically though, scientists and experts with this mindset are in the minority. The project's existence depends upon the majority and as Ross (1987) lists in his third question, the EIA must be understood by all who purview it. This will only happen if all who view the EIA and project plan are given the opportunity to quickly view and understand it instantly, to be quickly and easily taught the essential issues at stake in the project.

This requirement of instant understanding of complex environmental issues can not be achieved by presenting voluminous documents to stakeholders and regulators. Concise summaries and graphic visuals are required. Tools such as GIS might be suited for this task.

2.3. Environmental Elements (air, water, land...)

2.3.1 Characterization

According to Holling (1978), the nature and behaviour of ecological systems can be characterized by four properties of change. These properties have a dynamic that can be used to obtain a measure of the change due to an impact.

Properties

1. Relations between systems. Ecologically there are only a certain number of connections between species that create a certain organization. The understanding of this organization, defines the capacity, or results in a capacity of the ecosystem to absorb impacts. (For a more complete explanation see Holling, Chapter 2, 1978.)

2. Events are not uniform over space. There are patches of separate spatial elements that are linked but differ in their biological and physical makeups. They are linked by movements of energy and material. Therefore, impacts are not generally diluted over space but can be concentrated in one area.

3. Sharp shifts are natural. This can be characterized by chaos theory, bifurcation, and multiple levels of equilibrium. The hope is that these shifts can be predicted knowing the impact (Glieck, 1987).

4. Variability. This is a feature which contributes to persistence, self-monitoring, and self-correction. Ecology is constantly changing. "Placing a system in a straitjacket of constancy can cause fragility to evolve."(Holling, p. 34, 1978).

2.3.2 Categories/Elements

Westman (1985), Canter (1977), and Jain et al (1977), generally categorize the environment into the elements of air (particulates, gases), land, water. They can be seen as sources, as vectors, and as receptors of waste. They depend on topography and meteorology, and have physical, chemical, and biological attributes. They are also susceptible to geological dynamics, and the fact that land is an interface between the atmosphere, hydrosphere, and the lithosphere. Ecology/biology is another essential element. Since it is very difficult, in some cases impossible to identify and measure an impact on all the populations of all the species in a given area, a small subset of the organism population is measured. The small subset is carefully chosen and is referred to as an indicator species. Indicator species are:

> "Organisms that are particularly sensitive to the environmental stressor of interest. (They) are used as a guide to the health of all the species on the site" (Jain et al, p.33, 1977).

Plants are a major focus, along with the top of the food chain, which has smaller numbers and are therefore more susceptible to extinction and impact.

Other measurements that can be taken include energy fixation and flow through the ecosystem. Sound is another element. Health effects, and physical property damage are manifestations of deterioration of the quality of quietness.

Even after a focussing of effort, there could still be a wide variety of elements to be assessed in preparing an EIA. This data must still be managed. A data base system such as that used in GIS might be suitable for this task.

2.3.3 Assessment Methods or Steps

The elements listed vary along their spatial extents, or in a geographic area. Therefore, one of the steps taken in assessing impacts is the organization of the elemental measurement data in a geographic or spatial manner. Environmental management approaches include the establishment of geographically based air and watersheds for management boundaries, and plans of controlling the emissions within that area. A GIS tool, a spatial data base, could possibly be suitable for managing this data, and as a foundation for predictive modelling of assessment procedures.

The following steps for assessing the air pollution impact have been derived from Canter (1977), Westman (1985), Hyman and Stiftel (1988) and are included here as an example of the steps required to assess impacts.

1. Identification of pollutants and the rate of pollution. A calculation of pollutant emissions from the technical specifications of the physical/chemical process and technology used in a particular project or industrial development is usually a first step. Previous projects can be used as an example. Pollutants are categorized as to their effect on organisms, interaction with treatment technology, and interaction with human senses.

2. A description of the existing quality or a determination of the ambient emission standards and conditions. This deals with such issues as the prevention of soiling and deterioration of materials as well as the maintenance of visibility. This step includes the description of the flora and fauna in the area, and the identification of rare species. A description of any species management techniques being used in the area is also completed.
3. A determination of pollution dispersion potential and long distance transportation threats. This includes referring to the legislation concerning pollution rights.
4. A summarization of the meteorological data helps identify the geographic range of the impact.
5. A summarization of the emission inventory.
6. A determination of the mesoscale impact for a regional area.
7. A calculation of the concentrations for micro impacts. In order to predict ecological responses to pollutants:
   - species tolerances affected by the physical and chemical conditions, as well as atmospheric conditions must be ascertained,
   - organisms as indicators of environmental conditions must be identified,
   - ecosystem-level effects should be determined such as the gradient effect downwind or downstream of the project,
   - a patchwork differential response by species, should determine the degree of variation present in different key species' responses to impacts in different areas.

   Short term generation species will resist pollution effects better than long term populations.
8. A compilation and familiarity with the standards that are in place legislatively or through the scientific literature and experts.
9. A determination of the standards that are exceeded. Mitigation measures are considered for these exceedances. Separate standards are set for different broad target groups. One for humans, others for different species. Another variable is the dose, which is a function of the concentration and duration of exposure to the pollutant or impact. Average concentration, and peak concentration affect the dose. The mitigation measures are for management plans and emission controls.

2.4. Evaluation of Assessment Methods

2.4.1 Introduction

There is a problem in the evaluation of assessment methods. It deals with the inability at times to use a ratio valuation criteria on the environmental elements being assessed. This causes difficulty during decision making. According to Hyman & Stiftel (p.1, 1988):

> "The weakness in existing environmental assessment methods is in the valuation of impacts.
> Many conceptual and practical lessons can be learned by incorporating knowledge from the various social sciences with an understanding of the natural sciences."
>
> The assessors should "...stimulate the development of environmental assessment methods that integrate objective and subjective analysis in a way that is useful to the decision makers."

2.4.2 Impact Identification, Measurement, and Interpretation

Referring to Jain et al (1977), Munn (1979), the CPA (1991), Beanlands & Duinker (1983), and Canter (1977), the criteria for evaluating methodologies includes the checklist below. These criteria form a framework for detailed plans and tactics for completing an EIA. The checklist is segmented into phases of the EIA process.

Phase - Impact Identification

Criteria - *Complete ecological characterization.* The characterization should be comprehensive and the characterization method should be flexible for all environmental elements, types, sizes, scales, and ranges. The method must be specific and selective in identifying parameters to be examined.

- *Setting Boundaries*. Project impacts and complex problems should be isolated and bounded for purposes of examination.
- *Timing*. The timing and duration of impacts should be predicted. Data sources required should be identified.
- *Viewpoints*. Many perspectives and multiple objectives should be used for viewing a particular concern.
- *Bias*. Bias should be eliminated.

Phase - Impact Measurement

Criteria - *Explicit indicators that are measurable should be used.* These include as many magnitude measures as possible, and objective as opposed to subjective measures should be used.

Phase - Impact Interpretation

Criteria - *Prediction.* State of the art models and systems for predicting impacts. Dynamic short term and gradual long term change needs prediction.

- *Uncertainty.* The uncertainty and explicit degree of confidence in impact significance should be determined. The risk of impacts should be assessed by the assessment method.
- *Aggregation.* Aggregation and coordination for a net total impact, and prediction of interactions and accumulations, and indirect effects is required.
- *Priorities.* Environmentally sensitive areas, and a prioritization method should be established. Public involvement helps set the priorities.
- *Alternatives.* Mutually exclusive alternative generation and evaluation is required.

Other important criteria to consider in evaluating assessment methods include determining resource requirements such as data, manpower, time, costs, and technologies required. A lack of ambiguity in results and analyst bias to the study is an important scientific validation. The efficient use of time, money, and people indicates the quality of the EIA. The requirement to undertake, and plans made to undertake monitoring is also important.

2.4.3 Decision Focus

The EIA provides guidance for making informed tradeoffs between environmental quality and societal objectives. A more analytical approach to the presentation and interpretation of information on values could reduce conflicts among parties and help decision makers clarify their judgements. A careful choice of assessment method can greatly assist the decision maker.

Jain et al (1977) have four considerations in selecting the appropriate assessment methods or tools.

1. Tools should be used for decision making or providing information.

2. If the alternatives generated by an assessment method are incremental, this would allow a comparison of impacts. If they are fundamental they should be measured against an absolute standard.
3. Determine whether the degree of public involvement is: substantive participation or only review, and whether the public's views are directly incorporated within the assessment and subsequent project plan. This defines the type of product the EIA will need to produce.
4. The familiarity of impact assessors to the public issues, to the area, and type of development in question, defines the degree and depth of research to be undertaken. The makeup of the team is extremely important in choosing assessment methods. They will be familiar with and biased towards certain assessment methods.

Jain et al (1977), Munn (1979), Westman (1985), Mcharg (1969), Hyman & Stiftel (1988), and Canter (1977) describe a collection of assessment methods some of which can be found in Appendix A.

2.5. Team

2.5.1 Review of Team Objectives

As discussed in the previous environmental elements section, Beanlands & Duinker (1983) support the following approach for organizing the team preparing the EIA. For initial understanding an ecological characterization should be undertaken. This lays out the areas of importance, or focus for further in-depth work. Focus for the team is crucial. In support of prediction, the study of previous projects is advised along with pilot scale perturbations. For testing the hypothesis, baseline variables are listed in order to determine if the predictions made are in fact accurate.

2.5.2 Administrative Procedures for Assembling a Team

Holling (1978) suggests the technique of using two or more workshops. The workshop technique, involving a core group of experts, provides the brain for the body of the research team. The first workshop can begin to define the problem, form a backbone for a long term analysis of alternatives, and serve as a mode of information transfer to stakeholders and decision makers. A second workshop, if conducted, would have the model of the environment running and alternatives would be developed. Specialists making up the research team would have conducted a literature search and planned their research for the collection of additional data. Communication is the order of the day along with an exploration of the alternatives. Subsequent workshops incorporate the data from the specialists and again evaluate the results on the alternatives.

A honed version of the workshop method by Kennedy & Ross (1992) describes a focussed environmental assessment process. It focuses on "...assisting EIA in identifying, technically refining, and formulating management plans for environmental impacts." (Kennedy & Ross, 1992). The process is split into three stages.

1. Impact identification stage.
   This stage is the primary focussing or scoping stage. The most important from a large list of impacts are screened in this stage.
2. Assessment stage.
   This stage tries to formulate hypothesis and sets the framework for the scientific analysis of the impacts identified in the first stage.
3. Impact management planning stage.
   This is an impact monitoring and mitigation planning stage.

The scoping stage of the EIA process, essentially the early planning of the project, is crucial. If done properly the entire EIA project, and project life can all progress sustainably. The rest of the EIA, is important, but this early stage sets the tone for detailed study, design, implementation, operation, and potential abandonment of a facility. The team assembled must be cognizant of the importance of this initial scoping activity.

2.5.3 Personnel, Interdisciplinary integration

Beanlands & Duinker (1983) suggest the need for information transfer. Better communications between all the project participants concerning the EIA information and awareness of all problems is required. According to Wikstrom (1989), there is a need for scientists to start to integrate their knowledge, not to specialize. This is especially true for the economists and resource managers. The approach recommended by Holling (p. 1, 1978) is a theoretical view of integration:

> "... adaptive environmental management and policy design, (should) integrate(s) (the) environmental with (the) economic and social understanding at the very beginning of the design process, in a sequence of steps during the design phase and after implementation."

In the paper by Kennedy & Ross (1992), the use of multi-disciplinary teams is suggested at the scoping stage. The team develops the hypothesis as to impacts, and then judges the hypothesis as to its validity and importance in the project and environment. They state (p. 480), that the "...development of impact matrices also assists in achieving consensus among participants for further consideration of some project activities and environmental impacts." The authors go on to say (p. 482), that the "...exchange and integration of information among disciplines is important in ensuring a sound and balanced EIA."

Rodger (p.16, 1990) states that integration is important because it "cuts across all sectors". Integrating EIS facets involves the creation and use of common reference points for all disciplines. For an EIS the reference point is a thesaurus of environmental terms. This standardizes the data items (Rodger, p.103, 1990) and terms used by all the participants in the process.

The role of the environmental analysis team is to produce a model of the environment that will get the specialist to look outside his area of expertise to determine what inputs from other areas could effect his area. The specialists list the variables that come out of their system. The use of a leopold matrix (Holling, p. 74, 1978) for instance, can cross-reference variables to determine if they have an impact on one another.

Some of the people being supported by an integration of different disciplines are the:

- decision maker,
- assessor,
- project proponent,
- assessment reviewer,
- central and local government agencies,
- public (includes the press),
- non-governmental organizations,
- experts,
- adjacent governments,
- legislative branches,
- judiciary.

As mentioned in the administrative concerns section, a multi-sectoral integration must be achieved. A tool such as GIS is available for potentially helping accomplish this objective by organizing all the information into a common or central database.

2.5.4 Danger of Bias

Holling (1978) states that there are problems in terms of specialist's blinders, and Hyman & Stiftel (1988), and Westman (1985) comment that biases are a pitfall in environmental assessment. Subjective value judgements must avoid systemic bias. The types of bias that must be guarded against are: informational, instrumental, systemic, hypothetical, and strategic (Hyman & Stiftel, Chapter 2, 1988). The sectors of multiple publics participating also promote their own bias. Structured workshops are biased against busy and non-motivated people for instance. To reduce the effect of this particular bias, Hyman & Stiftel (1988) and Westman (1985) state that nature should be represented by special interest groups.

2.6. Evaluating alternatives

2.6.1 Alternative Generation

Westman (1985) fashions alternatives by starting at the conceptual level in order not to be constrained by prior decisions. National industrial level policy decisions should be considered at this point. The significance of the impacts of the alternatives must be assessed. The references previously cited generally support the following methods for fashioning alternatives:

1. Panel of Experts (Holling, 1978).
2. Interactive Computer Modelling (Holling, 1978).
3. Multicriteria Evaluation (MacLaren and Whitney, p. 222, 1985).

2.6.2 Decision Focus and Weightings

Munn (1979) brings attention to the fact that the assessor is not supposed to prepare a scientific treatise on the environment, but rather to help the decision maker choose amongst various alternatives and strategies. Decisions are shaped by the results of the assessment procedure and all the feedback obtained on the alternatives. This process forces the EIA to be an integral part of the project planning process.

Munn (1979) expands on Holling's (1978) interpretation of impact indicators. Careful attention and design of the display of the values given to indicators is required. If not the display or model could become as confusing as the environment itself. The alternatives within categories of indicators should be ranked. Normalization and weighting is required for further statistical analysis. Weights should come from the decision makers. The results can be aggregated, but extraordinary impacts that are obscured by aggregation should be highlighted. All the components of the aggregation should be identified.

This weighting exercise that should be done, and is done by the decision makers requires further explanation. The exercise is intrinsically tied to the significance issue raised previously. Potential impacts, and constraints are identified. The significance is tested by establishing what is important to the decision makers, public, and scientists, and includes matters whose significance is not totally known. In order to further examine significance and to ensure that the correct impacts are investigated, variables are identified that describe the significance. A hypothesis concerning the significant variables and the independent and dependent variables is specified. Then all reasonable alternatives for the sensitivity tests can be created for analysis.

For instance a panel of experts could be used. They would brainstorm, and could start, with a prior project checklist, modelling the ecosystem effected to predict impacts. Then they would postulate the effects of the impacts, confidence levels for the occurrence and the magnitude of these impacts. A Delphi (Linstone & Turoff, 1975), technique could be used for estimating impacts and iteration would occur between the experts to converge the estimates. Further research would involve a matrix analysis of the impacts and their probability of occurrence. This would try to integrate the possible events to estimate the total impact. A sensitivity analysis can also be made to determine which impacts and estimates are ductile enough to absorb a large error in their estimates and which are sensitive and clearly effect the total impact assessment with their alteration.

The basis for the sensitivity test can be case studies, models, laboratory studies, field perturbation experiments, and/or ecological theory. There should be an estimate of the likelihood of predictions. This affects any sensitivity analysis.

The evaluations of the significance of findings are left up to the decision maker. Weights could be affecting and helping determine significance. The sensitivity tests on determining the significant impacts identifies alternatives to the proposed action. Past project impacts are relevent at this point.

There is a need to perform a sensitivity analysis on the possible mitigation and reclamation activities the various alternatives entail. It is at this point that a recognition of trade-offs is imperative which may lead to revised development plans after impact assessment. Hyman & Stiftel (1988) view the alternative generation exercise as providing guidance for making informed tradeoffs between environmental quality and societal objectives.

2.6.3 Alternative Selection

Jain et al (p. 12, 1977) states that the key considerations to selecting alternatives are in determining if they have incremental or fundamental differences. Fundamental differences are measured against an absolute standard. Incremental differences allow relative alternative comparisons. In addition, impact interpretation of alternatives is based upon the significance of the input, the existence of explicit criteria to determine impact significance, the uncertainty or degree of confidence in impact significance, the risk of impacts, and an aggregation for a net total using a sensitivity analysis. The public and expert scientists are who select alternatives based on these considerations.

To Holling (1978), decision structures are hierarchical, one level's goal is another's policy. The evaluation that is suggested in his book involves first a generation of indicators. They are ecological, economic, or recreational and there usually is a client demand point. A client being a stakeholder or decision-maker. As well an informal policy comparison is done within the project group and within the legislative framework in the project's geographic area. At this point there can be a concentration upon the differences between alternatives among indicators. This can result in the preparation of hybrids combining various indicator highlights. For instance, a utility analysis in anthropocentric terms can be made. Then the uncertainties of objectives, model assumptions, and deviations from desired results are identified. The use of time horizons and discounting in a utility analysis case can have a variety of effects on the decision analysis.

Maclaren & Whitney (1985) promote a scientific approach. The major part of the assessment should be the formulation of specific hypothesis of impact. The testing of the hypothesis should be the basis of the assessment. Tradeoffs occur between minimizing risk of failure and minimizing consequences of the impact. Alternatives should be able to withstand certain impacts without failure. There can not be a strict attempt to eliminate consequences, but rather the system should be flexible enough to absorb the impacts. A pilot project could be used to limit the consequences, test the alternatives, and "face surprise with a system that is used to it" (Holling, 1978).

In the evaluation and selection, the goal is to define alternatives that have a high probability of working out if things go terribly wrong. The alternatives should explore the maximum benefit scenario, minimum cost of failure scenario, and the maximum probability of success scenario.

2.7. Decision making methods

2.7.1 Quantitative Methods

These are various quantitative methods whose main purposes are to optimize the decision and reduce conflict. Hyman & Stiftel's (p.1, 1988) position is worth repeating here:

> "...stimulate the development of environmental assessment methods that integrate objective and subjective analysis in a way that is useful to the decision makers."

During decision making subjective evaluations will be made. The subjective anthropocentric concerns that arise should be quantified wherever possible. Estimating the monetary benefits and costs of environmental quality can be done using various methods, some of which are listed by Hyman & Stiftel (p. 58, 1988) to help decision makers. Their list of methodologies are specifically designed to help the decision makers in their task, but some are more helpful and generally useful than others, (e.g. Social, Adaptive, Goals achievement Environmental Assessment SAGE). The estimate of monetary benefits could also be based upon social judgement theory by analyzing decisions (Hyman & Stiftel, p. 111, 1988).

Beanlands & Duinker (1983) state that the decision makers only have to be concerned with significant impacts. As Hyman & Stiftel (1988) state, a pitfall in environmental assessment is that the large amount of data that are collected are not geared to the needs of decision makers. Significant impacts are the ones that impact the project decisions that have to be made. If these are identified prior to the study being done, then concerted effort will go into the areas of greatest impact to the decision makers. If enough of a testing and prediction approach is used then the hypothesis that are drawn up will have been fully assessed to determine what their impact will be. The step prior to that must also be done, in that there must have been enough of a good project plan, good literature, and previous work in researching the area and previous projects, to ensure that a complete list of environmental elements have been looked at. The ones that are unimportant discarded, the significant ones looked at in more detail.

2.7.2 Concerns and Resolution of Concerns (Risk)

2.7.2.1 Definition of Risk

Risk according to Munn (1979) in an EIA results from uncertainties in three areas:

1. Environmental variability.
2. Environmental complexity due to a lack of understanding of the dynamics that cause environmental variability.
3. Inadequate data for the area.

Westman (1985) characterizes or defines risk factors as:

- risk that can be determined when all possible future outcomes and their respective probabilities of occurrence are known,
- uncertainty exists when all possible outcomes are known but probabilities of occurrence are unknown,
- incomplete knowledge exists when not all outcomes are known.

This definition is in line with the definition of risk found in the project management parameters of known unknowns and unknown unknowns. Risk perception studies indicate the relative acceptability of risk depends upon knowledge and control of exposure to the risk, as well as any benefit perceived from taking the risk. In planning a project conflicting risk sources can be created such as competing resource demands, and human value differences.

2.7.2.2 Methods of Managing Risk

Hyman & Stiftel (p.32, 1988) state that "...it is best to leave value judgements about risk acceptability to decision makers who are in contact with the full range of public opinion."

With uncertainty, the assessors need to indicate: ranges, key causal relationships, perform a sensitivity analysis of alternatives, and deal with margins of safety.
Value judgements made by decision makers can be succored with methods such as:
i) game theory,
ii) subjective probability - expert judgements are used, such as Holling's (1978) AEAM workshops,
iii) decision analysis, which is a method of analysis that can try to anticipate causes and effects of various sequences of decisions.

In the past, man has gone about living and surviving in a sea of unknown (Holling, Chapter 1, 1978). He has used trial and error as his main investigatory procedure. This method is unacceptable in the current arena (e.g. a nuclear facility). The way to get around this problem is to reduce the effect of unknowns; to design for uncertainty. The development of more resilient project plans can reduce uncertainty.

2.8. Communicating EIA Results to the Public

According to Holling (1978) four pieces of information should be communicated to the public:
1. Environmental baseline database measurements and assumptions.
2. An explanation of the technical method of analysis.

3. Results of the analysis.
4. Conclusions; actual numbers and degree of belief or confidence in the prediction of the effect of project impacts on the environment.

Canter identifies publics in two ways:

1) Directly concerned groups:
   i. Persons immediately effected.
   ii. Ecologists/conservationists willing to incur substantial costs for environmental protection.
   iii. Business developers.
   iv. General public that do not want to sacrifice their standard of living for environmental protection.
2) Indirectly concerned groups (See Appendix A for a more complete list.)

2.8.1 Attaining Effective Communications

Canter (p.41, 1977) suggests continuous, two-way communication. This communication involves promoting full public understanding of the processes and mechanisms through which environmental problems and needs are investigated and solved by the responsible team. The team should keep the public informed of the status of the studies and plans. It should actively solicit from all concerned citizens, their opinions and perceptions of objectives and needs, and preferences regarding resource usage and development alternatives. This is more of a participative approach and communication is a necessity of the participation. Participation moves in lockstep with communication.

Munn (1979) states the information should be provided in an appropriate form and timely manner. There should be no restrictions on individuals or organizations. The scientific jargon and measurement units should be well explained. The criteria and assumptions used in the study have to be very clearly communicated, and the affected parties or major stakeholders have to be identified as they are the consumers of the communicated information.

2.8.2 Concerns

Jain et al (1977), have concerns in terms of the public and the communication of the EIA's findings to the outside world. This communication of the EIA's findings is important and has a bearing on a variety of factors. The affected parties should be linked to the impacts that are predicted. There should be an adequate setting description, in order to fix the site being inspected. The summary format of the information being communicated is crucial for concisely ensuring key issues are highlighted. Finally, regulatory compliance must be absolutely evident. According to Holling (1978), public participation can be most effective when the public is fully informed, educated, and has free access to the decision makers.

2.8.3 Techniques for Communication

1. Participation provides gaming opportunities for what-if analysis and simulations. An understanding of the underlying structure of the assessment is the result of this participation and interactive what-if analysis.
2. Pictorial representations, graphs, and maps are powerful presentation aids. This combination of activities and graphical products can eventually lead the participants in the process to become more comfortable with the results. The confidence in these results also increases. This is an area that is particularly suited for a spatial data base such as GIS, which is exceptionally capable of pictorial presentation.

Public participation approaches usually depend on the communication channels and the levels of information complexity. The participation methods used are chosen by classifying a number of variables concerning the public:

- the extent to which the public has power over the decision,
- the information feedback approach required or requested,
- the level of consultation required,
- the degree of joint planning necessary,
- the delegated authority the public group has.

Prior to an approach of the public there is a need to identify:

- which people are to be reached,
- what power level is to be delegated to them, by whom will the delegation be done,
- what feedback is required,
- the areas where bias would most likely occur.

2.8.4 Benefits

Westman (1985) defines the public role as including the following responsibilities. The public should identify the range of impacts of the proposal, and evaluate the significance of the impacts. The public should comment on the fairness and completeness of the EIA, and be given information on the monitoring plans and contingencies if monitoring indicates problems. The public must be aware of mitigation needs and should highlite the significant areas of mitigation.

Canter (1977) lists the following benefits from public participation:

1. The naturally unrepresented are allowed to air their views.
2. The public can provide useful information to the decision makers.
3. Enhanced public confidence in the project and agency.
4. A safety valve for pent-up feelings.
5. Adds a level of accountability to the administrative and political decision makers.
6. Forces the agency to respond to issues beyond the immediate project.

2.8.5 Disadvantages

Some of the disadvantages are:

1. Confusion due to the plethora of issues brought forward.
2. Erroneous information from non-experts.
3. Increased project delay and cost.
4. The results of the participation are unknown.

The public's role in the process is crucial. The communication of the scientific results of an assessment to the public allows the public to make informed tradeoff decisions, but the delay that occurs in teaching the public the scientific issues and the consequences of their decisions is an area of further research for improvement.

2.9. Future Steps

Munn in a 1979 reference suggests that EIA research would progress in the following areas. There would be or should be post-audits testing EIA accuracy and completeness. A basic scientific evaluation of the EIA predictions and effectiveness would be required. The EIA criteria set at the beginning of an EIA process needed study. This study would determine if the most important criteria are consistently identified and if not why. A study of the method of quantifying qualitative judgements on the value of various components of the environmental quality would be required. Further development of modelling techniques for EIA to improve the predictions made in assessing impacts are necessary. A study of sociological effects and finally the study of the communication methods towards a non-technical audience of the results of the EIA process was a crucial area of future work and development. There was a definite requirement for streamlining the process and reducing the amount of time taken in preparing an EIA.

2.10. Concluding Comments

The research of the EIA process presented in this thesis identifies the areas of concentration for future work and improvement. An EIA prepared today must contain the following elements. The EIA must be focussed and have a scope that addresses stakeholder concerns. It must address legal and regulatory expectations. It must be scientifically organized as a study. Adequate data must be collected to describe the essential environmental elements of the area in question. The team preparing the EIA must be multi-disciplined and integrated in its work. The process of evaluating alternatives and preparing proper support for decision makers must be done efficiently. Communications to the stakeholders and the general public of the alternatives and the decisions made is the most important element, if done inadequately, it can undermine previous efforts.

Future work in the areas of monitoring and post-audits will cause these elements to become even more common than they currently are in EIA's. The quantification of qualitative evaluations should continue to progress, along with modelling capabilities. The communication methods used should also become more sophisticated and effective. Finally the entire process should become streamlined and less time consuming.

The areas in which a tool such as a GIS can be useful are first in the focussing or scoping procedure. This allows very quick conceptual modelling and planning of the EIA preparation. The GIS can be used to manage the enormous amounts of data that are gathered and accessed to describe the environmental elements of the area in question. Through this management of information, integration of the diverse environmental elements that are collected in an EIA occurs; thus integrating the work of the team preparing the EIA and allowing the EIA and project to benefit from the synergy produced. The evaluation of alternatives and modelling process can be facilitated if not actually accomplished within a GIS. The GIS is capable of supporting decisions through its graphic capabilities and in communicating those decisions and impacts to stakeholders and the public at large. It does this simply and with clarity, with graphic visual products. These are some of the capabilities that are the subject of the next section of this thesis, the GIS Chapter.

CHAPTER THREE - GEOGRAPHIC INFORMATION SYSTEMS

3.1. Geographic Information Systems (GIS) Definition

A GIS has been defined by Burrough (pp. 6-7, 1986) as:

> "...a set of tools for collecting, storing, retrieving at will, transforming, and displaying spatial data from the real world for a particular set of purposes."
>
> "Geographic data describe objects from the real world in terms of:
> (a) their position with respect to a known coordinate system,
> (b) their attributes that are unrelated to position (such as colour, cost, pH, incidence of disease, etc.) and,
> (c) their spatial interrelationships with each other (topological relations) which describe how they are linked together...".

Star & Estes (1990) view a GIS in terms of a manual geographic information system broken into components. To illustrate such a manual system a fictional project can be visualized. The components gathered are different data layers, maps, or overlays depicting different themes or thematic layers of data. Themes can come in various forms such as topographic maps, municipal boundary maps, and an aerial photograph. Typically they will not be planimetric. The horizontal relationships between objects on the ground will not be represented on all the maps consistently. Photographs, if they are used as a data layer, will suffer from perspective distortion and a non-vertical point-of-view. Registration, the redrawing of maps so that overlays duplicate features, will usually have to be done to prepare for analysis. The collection of maps, data sets, and layers can now be classified as a manual database; a spatially registered set of data planes or layers.

Marble et al (1984) define a GIS using generic concepts. First, geographic data has three basic characteristics:

- a physical characteristic (e.g. such as a soil type based on acidity levels.);
- its spatial location (e.g. a coordinate or location on the earth, showing where the physical characteristic is located.);
- a temporal characteristic (e.g. a temporal sequence of physical characteristic data at specific locations.).

Secondly, three notations, or what are known as primitives, are used for representing spatial locations of geographic phenomenon: a point, a line, or a polygon.

3.1.1 Cartographic Features (symbols)

There are certain cartographic details that GIS users have to be aware of. They define the map features or variables that can be manipulated in the creation and use of a map. Star & Estes (1990) and Marble et al (1984) list these map characteristics or cartographic features that must be understood as part of the mapping process and the basis on which a GIS can be partially built.

- Maps are scale reductions of the real object.
- A map usually must undergo a transformation from a curved to a flat surface.
- A map is an abstraction, not all of reality is portrayed there.
- Symbols are used on the map to represent reality.

Cartography deals with this conversion of spatial information into map symbolism. There are a variety of computer cartographic output and manipulation processes that can be used to communicate information. A sample of these is in Appendix B. In the process of symbolization of spatial data, selective assignment of map space to spatial entities is a concern. There is competition for space on the map, since it is a reduction of reality. Also the use of different projections alters the spatial visual relationships. Symbols chosen should try to reflect the attributes being modelled. A map legend explains the symbols literally, and explains visual relationships with the help of a coordinate grid. Care must be taken in having effective color display for map task performance (such as presentation before a regulatory board) in a computer environment. Problems arise in the interpretation of the visual display that the map provides, especially a computer map. There is a danger of overload, through the steps of transforming the data presented to the solution of the user's problem. Color is the main variable being altered. The computer can provide a multitude of colors but visually the nuances can be lost on a human reviewer.

3.2. GIS essential elements

Combining the works of: Star & Estes (1990), Marble et al (1984), Brassel (1989), and Tomlinson (1976) results in a list of the essential elements of GIS:

1. Data Acquisition

   It is important to know the underlying quality of information used. Their source and currency are also important.

2. Preprocessing:

This involves data format conversion and systematically identifying data object locations. Star & Estes (p.76, 1990) give a good simple explanation of the preprocessing required.

3. Data Management

   This is the creation of, and access to the database. Data management is also the storage and retrieval operation, including error correction.

4. Manipulation & Analysis

   This is the interpretation of the input data and the mathematical manipulation of it to respond to user queries.

5. Product Generation Reporting

   This is the output of the system and the variety of formats that can be used.

6. The GIS essential elements are all part of a flowing, continuous system.

This continuous or integrated system is a natural fit to the environment. The system is able to integrate different processes and levels of data. A model of the environment would necessarily require the integration of various scientific discipline results, such as plant and animal biology, geography, and meteorology.

Tomlinson (1976) describes the elements above but stresses data management, and analysis or information use systems. Tomlinson's article does not adequately break down the elements of the GIS in the required detail, but groups them conceptually. The Star & Estes list (p.24, 1990) identifies each element in reference to the computer process executed. This enables a better visualization of the individual elements and the entire GIS function.

3.2.1 Graphical User Interface (GUI)

Guptill (1988), McLaren (1989), and Guariso (1989) point out that a good GUI can lower the risk of rejection of a system by its users, reduce training times, and improve throughput in the system. Customization of the GUI menus according to user specifications is imperative in order to ensure user acceptance.

Burrough (1986) defines GUI as a series of menus, offering choices of actions to the users. Behind the menu command, language interpreters translate user input into computer code commands that the system performs. Defaults enable the system to continue and obtain some results regardless of the lack of user input and knowledge of the system.

Help windows and documentation explain the actions that the GIS executes. They explain exactly what is done, how it is done, and usually contain an example. Menu windows allow the system to interact with the user by asking for input and displaying results.

For instance, one commercially available system, ARC/INFO[5], has a method that allows a GUI to be custom made for users. Customizing is done with what is known as AML or Arc Macro Language. An AML program, which is somewhat similar to the C programming language, contains:

- directives to perform an action or to determine the flow of control,
- functions to perform text substitution,
- variables to perform text substitution.

Though a GUI is not specifically mentioned or explained in detail by Tomlinson (1976), Star & Estes (1990), or Burrough (1986), it is an essential component of a GIS. Future users of a GIS will not want to deal with the computer programs themselves, they will expect an easy to understand and use, menu driven program.

3.2.2 Data Aquisition

Star & Estes (1990) indicate one of the first steps in input to a GIS is data acquisition. Data arrives in a variety of forms both manual and digital. If existing hardcopy maps are used then the mapping standards should be in place or ascertained. These standards convey information about the accuracy and precision, currency, and spatial characteristics of the map. In order for the map data to be input, the information on it should be grouped into a set of points in the form of networks, in continuous fields, or in homogeneous discrete regions (i.e. polygons).

For the input of non-spatial data, elements to consider are the:

- date of data collection,
- observation criteria and source. The method used for observing and gathering the data and any inherent inaccuracies in this method need to be documented. This information is not directly applicable to a GIS, but it does indicate the relative accuracy of the final results that can be expected of a GIS.

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[5]Environmental Systems Research Institute (ESRI), Understanding GIS The ARC/INFO Method, ESRI Inc., Redlands, CA, 1990

- positional accuracy of the classes of the data,
- logical consistency and completeness of the data. The data in any one layer should be consistent and logical if it deals with only one theme.
- the level of uncertainty in the accuracy and precision of the data.

Spatial elements that are of concern in the acquisition phase are the:
- scale the data is portrayed in,
- resolution, or the actual size of the smallest visual element shown,
- coordinate system that is used to identify an entity's position,
- type of projection. This relates the data to the actual surface of the earth. The projection is the method used to portray the earth's curved surface onto a flat map.

Existing digital or analog data sets as opposed to field data gathering, are preferred whenever possible. This is because the above elements will theoretically have been dealt with. The result is a time savings inputting information to the system. This does not preclude the verification of the accuracy and precision of all digital maps obtained from these sources. There are a variety of sources of existing digital data. World coverage is uneven, however, remote sensing is addressing this problem. There are a multitude of government and private institutions offering data.

3.2.2.1 Digital Data Creation

Developing new digital data sets could occur when:
- existing data is insufficient,
- the validity of currently available data is unknown,
- the data you have, or can easily obtain, is irrelevant.

If the data is in the form of a hardcopy map for instance, the data could be digitized. Digitizing takes place using table and mouse hardware that records positions indicated by the mouse. Automated scanning reads documents such as photographs and images. The machine uses one, or a line of, photo detectors or CCD (charged coupled devices) which measure the brightness of the image they are exposed to (Star & Estes, p. 90, 1990). Once the data is in a digital form, verification is done to check the accuracy of the input process. Verification must be done to obtain spatial alignment or an identification of the relative position of the map's objects. Non-spatial associated attributes, such as those mentioned previously, are input also. Marble et al (1984) and Star & Estes (1990) described a number of practical examples as to some of the problems associated with digitizing. For a complete description of the digitizing process refer to Marble et al (Section 3, 1984).

Digitizing can be an arduous manual task. In some cases however, it is the quickest and most cost effective method of obtaining digital data. Unfortunately the method is prone to human error. Care must be taken in the digitizing and the editing or checking process. This is to ensure correct representation of the area being digitized. Mechanical methods, such as scanning are preferable to avoid the human error problem.

3.2.2.2 Remote Sensing

According to Star & Estes (1990) remote sensing is a very powerful data collection tool. GIS and remote sensing cannot reach their full potential unless they are linked. Remotely sensed data is only useful after adequate image interpretation. Image interpretation can be either manual, or computer assisted. An advantage of computer assisted digital image analysis is it is repeatable and can distinguish minute color changes undetectable to the eye. Machines process based on tone, color, patterns, and adjacency. Humans process the entire range of image elements including contextual information attached to the digital image, such as temporal information. Preprocessing is required to prepare the data for input to the GIS. Star & Estes (1990) describe this preprocessing step in detail.

According to Petersen et al (1989) remotely sensed data also presents problems with generating large data volumes. There is a need to reduce the physical amount of data being analyzed and collected by remote sensing. This is usually done through reorganizing the data and compressing it.

This is the method of choice for future data collection. The data is gathered in a digital format and requires less human manual handling than digitizing would require. Remote sensing can obtain an enormous amount of very precise data in a short period of time. This is an efficient and timely source of data in comparison to digitizing for instance. In the study of the environment, massive amounts of data can be gathered. The digital collection of this data is a function remote sensing is preforming currently.

3.2.2.3 Data quality

Burrough (1986) states that the cost of data aquisition significantly effects the error rates and the quality of the information derived from the data. There is no clear rationale behind the spatial occurrence of gathered data. Reality can be discontinuous. Fractal theory conceptually describes data's character (Gleick, 1987, Burrough, p11, 122, 1986). The reader is referred to Burrough (1986) for variables that measure data quality.

Within GIS type data, there is a natural variation component that leads to errors. The positional accuracy of the data could vary. The content accuracy, qualitative and quantitative, could vary. The data measurement or collection procedure could also vary. The measurement process could be altered due to the following:

- field data procedures could introduce errors,
- lab analysis of field data could cause errors to occur,
- spatial variation and map quality of the hardcopy could change, introducing errors.

Tomlinson (1976) is concerned with the quality of the source materials. Users of the map in the future require an acceptable base from which to refer. The clarity or sharpness of the image and attribute data on the map is important. Unambiguous image data and attribute data links must be discerned from the map. The map dataset must be complete. There should be a proper ratio of image to attribute data, enough to describe the images presented. The source materials should be free from extraneous data and there should be no missing data.

If remote sensing provides the data, some of the sources of error are [from Skidmore & Turner (1989), Marble et al (1984), Star & Estes (pp. 191-219, 1990)]:

- movement in the remote sensing platform,
- distortion due to the earth's curvature,
- distortion due to the platform itself, misalignment or a deterioration of sensor performance,
- radiometric errors from scattering of electro-magnetic waves,
- sensor calibration errors,
- scene specific errors due to the terrain topography altering the electro-magnetic waves received by the remote sensors,

- classification errors from poor spectral separation of classes.

Automatic error correction can be done by a GIS, or by digital image processing software. For instance systematic errors are corrected mathematically and irregular errors arising from the use of a certain projection, can be corrected using what is known as a rubber-sheeting technique (Star & Estes, p.106, 1990).

As the above lists indicate, there are many ways in which data can be corrupted. In order to usefully derive results from this data, it is essential that these corruptibility factors be recognized prior to data input. According to King et al (1989) a typical scenario is to rush to digitize the available data and not estimate the overheads for input and data quality errors that occur. This estimation of overheads should also include an estimation of confidence levels in the data itself. A full knowledge of the anticipated quality problems is required before deriving results from the analysis.

In GIS the adage of garbage-in garbage-out is very appropriately applied. There is a necessity for the analysis that goes on in a GIS to be mathematically aware of the error and the limits of the accuracy on the data. These limits effect the confidence of the results of GIS analysis (Gong, Crain, and Chapman, 1992).

3.2.2.4 Pre-processing

According to Star & Estes (1990) the reason for preprocessing GIS data is to create a coordinated set of thematic data layers. These are used for any analysis being attempted in a project. There are a variety of procedures for altering the different data sets in order to produce comparable thematic data layers. Seven of these procedures are listed below.

1. Format conversion. This involves converting between, and within different types, of raster and vector formats. There are also data medium conversions. These are conversions from floppy to hard drive for instance.
2. Data reduction and generalization. Generalization is a less precise representation than the original data. Data points can also generalize the data by taking pairs and using their average. Other numerical algorithms perform similar generalizations of the data.
3. Error detection and editing. During a digitizing process vectors are input and polygons created. The editing process can for instance close polygon boundaries. It also can eliminate slivers, duplication, attribute errors, and gaps.

4. Merging. This is the process of building complex objects from elemental points. Line snapping is an example of this. Again the creation of polygons from vectors is another example of merging.
5. Edge Matching. Instances may arise when a study region might stretch over more than one map sheet. In this case the edges must be aligned or matched perfectly to create one seamless dataset.
6. Rectification. This is the manipulation of objects so that they correspond to a specific coordinate system.
7. Registration. This is changing the view of a spatial relationship to agree with another with no concern for the referencing system.

Preprocessing creates the different thematic data layers, ensures that they refer to exactly the same geographic area, and allows analysis and comparison of the layers.

3.2.3 Data management

According to Star & Estes (1990) and Marble et al (p. 14, 1984) data management in a GIS is essential as it makes the information available to the users. Logical data is as it appears to the user, physical data is as it appears on the storage medium (fixed length and variable length data records). Data Base Management Systems (DBMS) hide these physical details from the user. The DBMS allows logical views to be customized to suit the user's needs.

These are typical DBMS tasks:

- Data Definition. The data dictionary contains data about the data (Chambers, 1989); data base design documentation. It contains a description of all items and codes for each thematic data layer. This serves to support development of legends.
- Insertion, creation, deletion, modification of new and existing records (attributes, polygons, arcs, points).
- Query, search, retrieval, listing/display, of the spatial objects and the attributes are handled by the DBMS.
- Security of the data is enforced by the DBMS by providing for passwords, login commands and activity logs.
- Integrity of the data enforces necessary structural constraints on the internal storage of the data and its subsequent manipulation.

- Synchronization for multiple users of the same data.
- Minimization of redundancy.
- Independence from hardware configurations.
- Windowing manipulations.

Referring to the works of Star & Estes (1990), Marble et al (1984), and Chambers (1989), will result in a larger list of management functions of a DBMS.

3.2.3.1 Design

In designing a DBMS, Star & Estes (1990) comment that efficiency considerations in terms of physical storage of the data must be taken into account. The tradeoffs of theoretical preferences (raster or vector formats for instance) for the system, against the practical system operations must be assessed. Decisions must be made to take optimal advantage of each side of this tradeoff. For instance, consider the case of a circle. In a vector format; a point for the center, a radius, and the fact that it is a circle would be stored. In a raster format, each cell on a circle's circumference would have to be stored. File structure design, depends upon the complexity of the data structures. This in turn depends upon the required data manipulations to be performed, and the type of computer processing (mathematics) to be done (Star & Estes, p. 132, 1990). The users define this, and a multiplicity of users makes this difficult to optimize.

Spooner (1989) approaches the design issue visually. The map is of more use when stored as a database rather than as a picture. Design objectives should therefore determine how geographic features are identified and modelled. They should determine how information about the environmental attributes is held, and how the topology or information about relations is stored.

Guptill (1989) considers the following design criteria. Justification of the GIS might not occur if there is difficulty collecting data. Data collection could be mitigated by searching for existing sources of the data. Such sources would have the data in digital form already. If the data is available this would indicate an initial structure for the data. Subsequent alterations and conversion of the data depends entirely on the output required and the cost of the conversion. If there is no digital data available, the final structure of the data might dictate the method of data capture. For instance if there is a need for finely tuned data and the capture method is coarse then a problem arises.

Once the data input, data capture strategy, file structure, and application are defined, the technical requirements can be planned. Technical requirements such as estimates of the data volume, comes from the products required and the density of graphic information expected in order to make the required decisions. This also drives the planning process back to the structure being used and the data compression method used for storage.

Uhlenbruck et al (1989) has a number of distinct design features that make GIS stand apart from conventional DBMS.

1. Long data records.
2. Complex objects.
3. A large number of spatial relationships are possible among objects.
4. Large number of spatial operators are required to manipulate the objects.
5. Long transactions in terms of map revisions.
6. Complex consistency checking algorithms required. Visual checking of spatial errors.
7. Temporal data is often used, increasing data volumes. Long term storage of the data is required to facilitate comparison of temporal data sets.

3.2.3.2 Modes of Access or Query

The GIS must provide different modes of access for spatial and non-spatial data. Efficient data retrieval depends on four items:

i) The volume of data stored will influence the time the GIS takes in retrieving the requested information.

ii) The design of the data structure.

iii) The method of data encoding.

iv) Complexity of the query is dependant on the previous three items. Query systems are accompanied by a language interpreter to interface with users. GIS queries are more complex than the retrieval of non-spatial attributes information from a non-spatial database.

Uhlenbruck et al (1989) suggest system techniques that streamline the query search operation. They include:

- Paging, which subdivides the regions to use smaller data sets.
- Specifying a spatial window or a certain geographic area of interest.
- Using high order descriptions of various objects such as perimeter, area, and centroid.
- Hierarchical storage of data.
- Topological encoding to store specific relationships.

3.2.3.3 Storage Organizations

The data files have to be organized in a computer for easy access, updating, and retrieval. Along with hiearchical, a one to many relational data base organization, three other data base structures are mentioned below.

1. RELATIONAL

   According to Uhlenbruck et al (1989), relational databases are the method of choice. They have the disadvantage of slow processing due to unordered data, and system overheads. Disk access is the main cause of these problems. There are however, ways to improve access times. The data can be clustered by way of logically or spatially related data. For example the quadtree approach (Star & Estes, p.42, 1990) for the storage of raster data can be used. Uhlenbruck et al (1989) mention, other methods for storage and data organization in an attempt to streamline query operations, but they are beyond the scope of this paper.

2. NETWORK

   Guariso (1989) defines a network as an ordered list that can go backwards and forwards through the use of pointers. [See Guariso (1989) for a complete explanation.]

3. OBJECT ORIENTED

   Object-oriented databases are where a physical entity becomes an object with unique characteristics. The object has the ability to perform various functions or operations particular to the object. Information can be passed between objects. These databases are not commonly used presently.

A strength of any DBMS is its data storage capabilities. The ability to organize the storage and rapid retrieval of a large set of data is particularly useful in the environmental field. Voluminous amounts of data can be generated in an environmental study. A GIS's ability to manage this data makes the environmental study more effective.

3.2.3.4 Topology

Topology is the relations that the GIS maintains between objects or data items in the database. Topology "focuses on the connectivity and contiguity within and between figures" (Spooner, p. 75, 1989). The map should convey the interrelationships of the data, such as features and the associations between features. Topological relationships exist between the different data objects present in a GIS. Spooner helps define topology by describing three aspects:

- Sharing. The sharing of spatial objects that are part of a higher level spatial object (i.e. a line of a polygon).
- Connectivity. The relations between points and lines.
- Adjacency. The knowledge of objects for example on either side of the main object of interest.

Queries that are based on topology do not need to reference distances or coordinates in their description of the relations between objects. The integrity of this information is ensured because relations are maintained throughout an editing operation that might move an object. The relationships that exist, the topology, would remain upon removal of middle elements such as a node between two lines. Topology could theoretically be coordinate free. For example a schematic map can be pictured, with no required real world coordinates, only topological relations, or landmarks to guide the users and familiarize them with the map's features.

3.2.3.5 Data Structures

Data structures chosen for a database are still an important issue even though some GIS's are able to process both raster and vector structures. According to Star & Estes (1990) , data structures for visual information affects data storage volume and processing efficiency. Comparisons should be made on the basis of data volume or storage efficiency, retrieval efficiency, robustness to perturbation, data manipulation efficiency, data accuracy, and data display. See Burrough (1986) and Guptill (1989) for a complete explanation of raster and vector structures.

3.2.4 Manipulation and Analysis

The manipulation process is generally for the purpose of arranging the data and information that is in a GIS in a unique and special way. This unique arrangement is usually for the purpose of answering specific questions and helping solve a decision maker's problems. The manipulations are listed in much of the literature [Burrough (1986), Star & Estes (1990), Marble et al (1984)], and a compendium of the more common techniques can be found in Appendix B.

In summary, the manipulations are dependant upon the final objective of the analysis. The objective defines what data is required for analysis and the subsequent steps that analysis must take. Analysis in GIS is facilitated by an extraordinary array of tools. Once spatial and attribute data are in digital form, they can be modified extensively.

One of the more prevalent functions used is the reclassification of categories. Existing attributes are altered in an attempt to prepare a particular map layer for additional analysis. Other prevalent functions are aggregation and overlay. The aggregation function is used to collect different spatial areas that are similar or are required to be classified jointly. Aggregation would group them for further processing. The overlay function combines usually two different layer's geographically homogeneous regions in an effort to compare the areas they have in common or where they diverge.

Geometric operations may be performed. They include operations such as:

- rectification,
- registration,
- area calculations of polygons,
- centroid determinations,
- shortest route calculations,
- slope and aspect calculations.

Statistical operations may also be performed on the data. Modelling completes this preliminary list of some of the manipulation tools available in a GIS.

The manipulations listed: overlays, reclassifications and modelling, are useful in analyzing environmental effects. What-if analysis can create predictions of the impacts of development in the environment.

3.2.5 The Product - GIS Output

Output hardcopy rates have 4 constraints:

- availability of data,
- availability of trained personnel,
- GIS processing ability,
- output device speed.

According to Guptill (1989), the objective is to present the data to correctly display the information and have it understood by the users and decision makers. The portrayed information about the subject cannot be inaccurate, misleading, or biased. Effective use of the different presentation media and techniques help to ensure an effective presentation. An explanation of the elements in a well designed visual presentation is found in Tufte (1986) .

According to Star & Estes (1990) there are different GIS display types. Which display type to use depends on a number of variables, some of the important of which are:

- the nature of the data (discrete or continuous),
- the required scale and resolution of the output,
- the hardware and software resolution available, the limiting constraints of the hardware,
- the ultimate audience and their sophistication,
- the transferability of the data for use in other systems.

The different display types are:

1. Maps:
   - thematic maps portray the structure of a given distribution of data.
   - chloropleth maps communicate relative magnitudes of continuous variables.
   - proximal/dasymetric maps focus on location and magnitude of areas exhibiting relative uniformity.
   - contour or isarithmic maps represent quantities by lines of equal value, emphasis is placed on gradients among values.
   - a dot map's symbol size represents a variable.
   - vector maps show direction and magnitude of directional flows.
   - landscape maps depict the earth's surface as viewed from an oblique aerial point of view.

- cartogram data is displayed based on some other value than area for its size.
- animated maps can show temporal changes that data and an area experience.

2. Graphics:

A graphics product must be able to stand alone (Refer to Tufte's (1983) *The Visual Display of Quantitative Information*). Bar charts, pie charts, scatter plots, histograms are examples of graphics products.
Numerical products include statistical analysis for quality assurance of the data and for indicating such things as patterns in a data layer.

Printers, plotters, film or CRT, video display monitors can give hard or soft copies of the GIS output. With the increasing portability of the hardware soft GIS output is becoming more convenient.

Visual information, pictures and graphs, are more effective at communicating information simply and quickly to diverse audiences. For instance, a table of coordinates signifying wildlife populations is more difficult to use in a site selection exercise, than the same wildlife population data displayed on a map of the area.

3.3. Implementation

The implementation of a GIS is a complicated project. Fortunately there has been a fair amount of work done in systematizing the process. Three actions are taken in a GIS implementation. The main plan to follow is the User Requirements Analysis (URA). The next important action taken is the completion of a pilot study. The final step is a benchmark project. This section initially describes some preliminary background design issues for preparing a GIS implementation.

3.3.1 Preliminary Activities

Harrison and Dangermond list five preliminary activities that have to be completed before there can be a GIS implementation.

1. Conceptual system design.
2. System acquisition and installation.
3. Data base development.
4. Application development.
5. Training and services.

The authors go on to describe what can be classified as a work breakdown structure for the implementation of a GIS, cross referencing the activities with the life cycle of a GIS. This is essential in planning a GIS implementation. In support of these preliminary activities Burrough helps choose a GIS by conceptually defining the user needs. There are three kinds of users and user situations that a GIS is introduced into.

1. A well defined task could be established for a GIS.
2. A partly defined task, with large unknown areas present could occur.
3. The most complicated and usual situation is an ad hoc arrangement, every job/task is different for the GIS.

3.3.2 Financial Implementation Estimates

The financing needs must be met with a well defined, well argued plan.

- Operational costs must be estimated.
- Costing a GIS involves preparing estimates for the following components:
  - Hardware and software, and personnel to support these tools.
  - Data input costs can be substantial. This includes entry of spatial data using scanners and digitizing. The costs to input non-spatial attributes, which could be text files, should be considered in this estimate.
  - The linking of systems and possibly software is usually required for the variety of interfaces that must be built between the existing systems and the new GIS system.
  - The costs of data output materials and equipment.
  - The cost of software for analysis, or the actual GIS modules required have to be obtained from a supplier.

- In terms of actual costs for system operations; memory size, and data handling is more important than processing costs.
- Assessment of the personnel is required to see what expertise is on staff and where and how much it would cost for expertise to be developed.
- The organizational aspects, which are discussed in more detail later in this paper, must be addressed. It must be determined how the computer department will be run in the future, and from where their financial support will originate. The interdepartmental effects in terms of information flow and cost benefit will further define costs and potential delays in implementation of the GIS and its operations. The data ownership and responsibility conflicts are contentious issues that must be resolved.

The list above is an organized approach to the planning of a systems implementation. The complexity of the system requires the application of good project management principles to ensure that this plan is prepared and used as a guide in GIS implementations.

3.3.3 Preliminary Design Issues

Chambers (1989) has also suggested that for implementing a GIS there should be a strict avoidance of rushing to obtain results. He supports the use of a URA, data base design, and a pilot study before full scale production.

The design of a GIS involves four primary components:

1. Cartographic layers design. In order to efficiently prepare layers, data to data relationships, topology, and data to function relationships must be planned. The planning of how these relationships will be organized should try to ensure: consistency, minimum data capture, efficiency, ongoing data management, and flexibility.

2. Feature attribute table and look-up table design. According to Chambers (1989) there usually is a separation of the database from the spatial geographic storage data.

   As explained previously, the physical makeup of the relational database, its administrative overhead, significantly effects its performance. Each database management operation will be effected by the underlying structure. An inefficient structure will perform progressively worse as data volumes increase and the system ages and evolves. A design rule of thumb to follow which deals with this is:

" A database that must support a wide variety of user views and applications should have a more basic and primitive organization." (Chambers, p.3, 1989).

This design which Chambers (1989) classifies as map library design will affect: data base maintenance, data query, and system performance, and disk storage requirements.

3. Documentation of the data and the system is essential, especially if users and managers of the system are not its creators. As well, on-line data dictionaries are helpful. Descriptions of the data should include accuracy and precision tolerances.

4. A pilot study should be attempted before full scale implementation. This should incorporate all layers required under a full scale implementation, and exhibit as full a range of complexity, as the full scale implementation. The pilot study should document all peer reviews of the output, and should limit the geographic area.

   Some of the benefits of a pilot study are the:

   - testing of database design performance,
   - development of procedures for the full scale system,
   - identification of obstacles to implementation,
   - investigation and the development of specifications for input,
   - gaining of continued management support.

Once the pilot study is completed, and assuming favourable results, a benchmarking exercise should be completed along with the establishment of a close supplier relationship. The personnel involved need to be generalists with the ability to synthesize the wide variety of information being used for design. User involvement is paramount and the need to simplify the system is imperative.

3.3.4 User Requirements Analysis (URA)

The works of Tomlinson (1976), Star & Estes (1990), Burrough (1986), and Guptill (1989) fully define the URA. The implementation of a GIS depends upon well defined user requirements. A URA should result in a "clear statement of end-product characteristics, required production rates, estimated data volumes, and a cost-benefit rationale." (Guptill, p. 11, 1989). The URA should not only analyze the current uses of the maps, but should go back a step to determine the purpose of the map, and define the underlying requirements, steps, and decisions that led to the map use. Once the underlying purposes are determined then a re-planning of the work being done can occur in an attempt to improve and streamline the work by using a GIS. Opportunities occur in using GIS that would not be apparent to the users that are currently ignorant of the system's capabilities. Guptill's work continues and explains the following steps required to perform an URA. The reader is referred to Guptill (1989) for a complete explanation of these steps.

Who Should Perform the URA?
Identification of Users.
Definition of Required Products.
Evaluation of Work Flow.
Data Base Development.
Refinement of GIS Product Characteristics.
Production Rates of Output.
Estimating Data Volumes.
Cost-Benefit Analysis.
Production of the URA report.

Results and Evaluation of the URA

If the assessment is positive then a list of application criteria is prepared for the specifications defining the scope of the system. A pilot project can then be planned. The application criteria are the list of must haves, and wanted GIS operational characteristics.

3.3.5 Benchmark

Guptill (p.45, 1989) and McLaren (1989) recommend a benchmarking process for evaluating GIS technology.

3.3.5.1 General Procedures

The purpose of the benchmark is to provide a mechanism for the evaluation of a system's suitability and efficiency. This exposes 'vapor' ware, i.e. software that is not available. The process allows the entire software company to be evaluated for determining its capabilities. The actual state of the art comes into clearer focus. Various departments see the capabilities of the system and commit to it. The entire URA initiates the commitment of people to the project. When they participate in a benchmark, their commitment is reinforced. The benchmark should be planned using the results of the URA. It serves as the guideline for the GIS capabilities that should be investigated. Appropriate data volumes, and specific functional and performance specifications should be tested.

3.3.5.2 Benchmark content

A benchmark can not cover all functions in a system. Rather it should try to test enough so as to take into account the user's mix of applications and data sets to enable extrapolation of the results to encompass the entire system's operations. The content of the test should expose any crucial inadequacies. A benchmark should allow analysis of the functions in terms of their:

- existence,
- efficiency of approach,
- performance (elapsed time) to perform various functions,
- limitations and constraints,
- consistency,
- correctness,
- security compliance,
- customizability to the user's environment.

The user should define tests of key aspects, some of which are found in Appendix B. The reader is referred to Guptill (Ch. 9, 1989) for a set of steps for conducting benchmarks.

3.3.6 People/organizations

The people, and the organization they are in, are key to a GIS implementation. Lo & Hilditch (1992) say a GIS can be used as a facilitating tool between many sub-organizational components. Crain (1987) states that GIS implementation has an input problem that is part of the organizational implementation of a GIS. He classified the input problem into the following two sections:

1. Institutional

This deals with the ownership and management of the GIS. GIS implementation usually crosses many if not all bureaucratic boundaries. Data sharing is essential for GIS to be an effective tool. If data ownership is not democratic, then the system's benefits become muted to the organization as a whole, and are only seen by one particular group within the organization. Solutions in counter acting this problem include:

- There should be sufficient top management visibility in the GIS implementation.
- The group responsible for the system should have a corporate wide breadth to its mandate.
- The GIS should provide output or products to all affected groups and to the organization as a whole.
- The owner or manager of the GIS data should have the respect of the user community.
- A computer communications network should be considered for the integration of information.

Crain (1992) suggests not to place the system too low in the organization, to not place it with an advanced group, or with an administrative unit.

2. Organizational administration

There must be a clear determination of the responsibilities for data input, ownership, use, maintenance, training, and upgrading. The sectors of the organization having these responsibilities must be sure of their roles by knowing which roles are independent, and which are shared between a number of different sections. Information to obtain, and factors to consider in defining these responsibilities are:

- An identification of the data owner.
- A list of the data owner responsibilities.
- An identification of user needs, which is usually different from those of the data owner. This defines the boundaries of the GIS service supplier and the data owner.

In the definition of responsibilities there is a need to avoid ambiguity in defining roles. This helps ensure the establishment of measurable specifications. During implementation there must be an avoidance of postponing the making of the required organizational changes. This ensures effective use of the system is made by capable people. Promoting the technology and communicating the advantages of the technology, should not be done prematurely. At all costs there should be an avoidance of the creation of unconnected sectoral data sets. A situation of private data ownership by some departments, will result in a destruction of the GIS's integration of data.

The Environmental Protection Agency's (EPA) experience stresses the importance of people and the facilitative properties of GIS. Holmes (1992) says that the use of GIS at the EPA coincided with the strategy of geographical initiatives. The geographic boundaries dictated the extent of the areas to be covered. The GIS allowed integration of the various personnel/departmental relationships in the geographic boundaries. Implementation of the GIS required a team of cross representational individuals to be assembled (ie. air, water, land). In the EPA's opinion the issue at the heart of a GIS implementation is data, or a lack of correct data. The GIS cannot be placed under the direction of the computer department since they know little of the data. The threat to the organizational group's autonomy at the EPA has been assuaged with access to the technology of GIS. GIS allows for the integration across scientific disciplines and organizational groups.

According to ESRI[6], people are fundamental to the GIS implementation success. ESRI lists the people making up the team required for a GIS implementation pilot and benchmarking project. These people are not usually on the project on a full time basis, rather they are used as needed.

3.4. Advantages

Marble et al (1984) see the advantages to using a GIS mainly in the two areas of compact data storage, and low cost maintenance and information retrieval. Campbell et al (1989) agree, stating that a GIS locates and logistically arranges the data. The GIS aggregates the data, manages, and processes the data from a variety of sources. The GIS allows the data to be displayed and analyzed spatially with ease. The results of various

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6______, Implementing a GIS: Necessary Functions, Successful Strategies ARC News, Vol.11, No. 4, 1989, ESRI, Redlands, California.

models can be plainly seen and efficiently run in order to quickly interpret different modelling assumption effects.

Paoli et al derive advantages using GIS for data collection.

> "GIS enhances data management capabilities by providing tools for organizing, reclassifying, combining, and updating, the data that are collected." (Paoli et al, p. 183, 1992).

The data collected in this example was from a variety of sources, in different formats and scales. Changes and additions were kept track of and were dictated by the project, an environmental investigation process. This allowed and kept track of the original baseline and the resulting changes to it from all the environmental constraints that evolved from different user inputs. This saved a tremendous amount of effort while mapping the information.

Spooner (1989) lauds the use of a topologically related database. The strength of topology is its contribution to the optimization of the spatial query, and the integrity of the data. A GIS relates graphic and non-graphic data.

Rapid testing of models can occur, which "... facilitates the evaluation of policy and scientific criteria over large areas quickly" (Spooner, pp. 1-26, 1989). In the Paoli et al (1992) paper the intention of using GIS was to provide a quick feedback system for the decision makers to evaluate the alternatives and visually see the results of their decisions.

Some types of analysis can not be performed manually in any cost-effective manner. With a GIS, the result is a tendency to integrate data collection, analysis, and decision making in one process. This coordinates and streamlines analysis.

Dangermond (1989) says a GIS, through its interrelating powers, can begin to have different institutions co-operate to a greater extent. The problems that each institution faces can be seen, in a geographic context, impacting all the resources and investment possibilities that are under the jurisdiction of the institutions. The GIS might be able to profoundly effect the way in which the institutions manage the resources. This is an opportunity for

GIS because there are indications that institutions have difficulty managing resources in a comprehensive manner.

The GIS performs an aggregation function. The vast amount of data that is available for describing a spatial area is overwhelming. The basic philosophy behind a GIS is to display the data as a map. The map is an abstract model that is visually identifiable to humans, while at the same time containing an incredible amount of data. The GIS adequately organizes the data into a representational form of output, a visual picture that can be comprehended by the human user.

Yapa (1991) states that:

> "the use of local renewable resources involves the adoption of end use analysis. There is a matching of end-uses to specific sources so as to minimize the consumption of material and energy (i.e.,minimize entropy). This matching requires a great deal of information which leads to what may be called the 'information-entropy trade-off'; minimization of entropy requires an inverse increase in information."

The author goes on to say that GIS could help manage the information part of the trade-off.

Holmes (1992) states the following advantages with the use of GIS at the EPA.

1. Helped communicate with the public.
2. Streamlined the debates and public forums.
3. There is an integration of team work on projects.
4. Streamlined the clean-up projects for environmental reclamation.
5. Spatial visualization is a time saver.
6. Economically the benefits were:
   - Improved data quality, compact electronic data storage.
   - Integration of data from other sources.
   - The ability to use multi-media techniques for the display of the results of a GIS analysis to surpass in quality manually prepared paper map presentations.

3.4.2 Need

A need for the technology or GIS tool does exist. In order for any tool such as this to be accepted and used effectively, there must be a need for it. Luscombe & Allen (1989) suggest that there is a predominant need for GIS. Environmental degradation threatens humankind. In developing countries, there is a need for better management of resource data. This information gathering must be demand driven. GIS is seen as an important tool in addressing information needs. The lending program of the World Bank focuses on these issues of gathering enough information to make the best lending decisions.

There is a major problem with assessing a developing country's plans and environments. There is a " lack of precise and comprehensive data about the extent, location, and specific causes and effects of these problems" (Luscombe & Allen, 1989). Usually there is no baseline data in a developing country. Data collection and management must be coordinated to a greater degree than is sometimes possible in exotic locales, and politically unstable areas. No system of any kind is at work there. There is a need for standards to be set for the data that is collected. There will be a need to integrate various information that is in a variety of formats. The institutions in the countries have to be strengthened to manage this process.

International lending institutions require new tools. The World Bank wants to monitor its investments by way of environmental effect. It encourages the creation of standardized information on resources in order to encourage better long term planning. Neredjick & Handelsman (1989) state that the UN policy is to only undertake projects in the resource development field that are economically feasible.

Data capture and input will become more sophisticated technologically (using remote sensing for data collection for instance), which probably means accessing and storing more data. The resource data is so vast, that parallel processing, integration of sources, and elimination of duplication must be achieved with a tool such as a GIS.

Both Luscombe & Neredjick (1989) approach GIS as a tool for resource management and environmental planning. Their particular focus is on the developing world. Unfortunately the projects in that area of the world do not usually result in a large return to the investors in the technology. A return is required in order for advances in the development of GIS. This part of the world is the area in which the use of a GIS is most advantageous.

3.5. Future steps

3.5.1 Introduction

According to Star & Estes (1990), GIS, in a decision support role, ideally should achieve the following objectives. It must be able to work with large heterogeneous spatial databases. It must be able to query the database about the existence, location, and characteristics of a wide variety of objects. It must operate efficiently, so that the user can work interactively with the underlying data and the required data analysis models. It must be easy to tailor to a variety of applications, as well as to many kinds of users. In addition it must be able to "learn" in significant ways, about the data and the user's objectives. Finally, it must be able to supply a readily interpretable output product for the ultimate users of the system.

3.5.2 Advancement Areas

Crain (1989) feels that GIS will be the key tool in monitoring, assessing and reporting on global resources. There are three areas that GIS is and should be expanding into. First, it should expand horizontally by integrating or expanding its spatial extents. Second there should be vertical integration with the use of more layers. Finally there needs to be more application sophistication, specifically the use of sophisticated modelling packages, relational, and object oriented databases. Advancements in what-if analysis packages is occurring presently, to satisfy this system development need.

On the environmental front the concept of sustainable development suggests:

> "a strong need for scientifically sound and consistent data for monitoring and assessment on a national, regional, and global basis and, as importantly, for the information systems to apply complex models on the long term inter-relations of the socio-economic and environmental factors." (Crain, p. 632, 1989).

The ability to model the long term impacts on the socio-economic and environmental factors help stakeholders in a project predict the effect their near term decisions will have. Therefore the GIS application of the future will typically play a decision support role through its modelling capabilities.

The GIS of the future might look like Figure 3.1. As shown the major components are:

- a spatial integrator of data from a variety of sources,

- a modelling engine, able to build complex scenarios (artificial intelligence),
- an intelligent interface that effectively optimizes and translates user queries for the system and provides the reverse translation to the user.

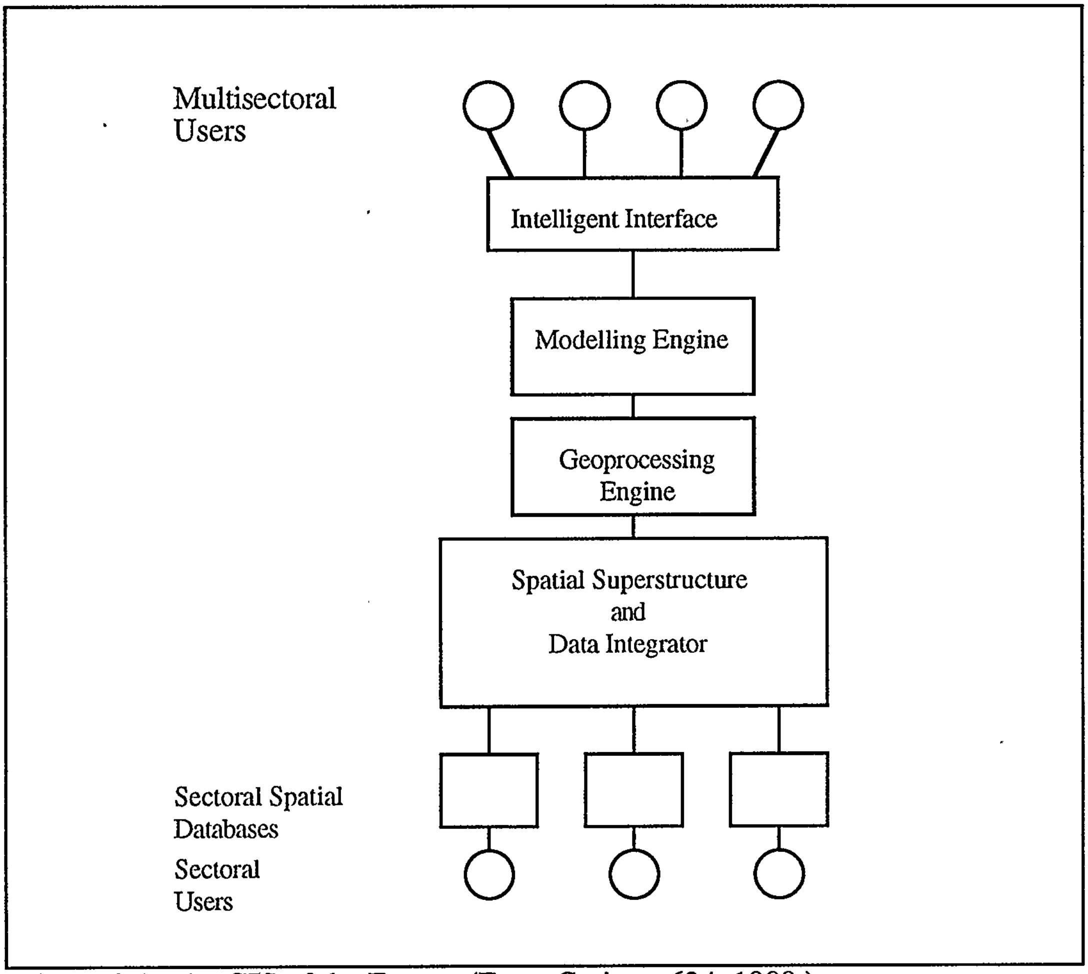

Figure 3.1 The GIS of the Future (From Crain, p.634, 1989.)

Peterson et al (1989) focus on the need to reduce the amount of data being analyzed and collected by remote sensing and other methods of surveying. They suggest the use of relationships among existing data. Examples used are elevation data, climatology, and soil landscapes. These layers are built up on top of one another in an effort to model soils without gathering incredible amounts of data. The authors mention three database factors that are brought to bear on the problem of data.

1. Established standards for the collection of data.
2. Knowing the uncertainty interval of the data.
3. Knowing the spatial and temporal scales that must be managed.

3.5.3 Errors and the Data Quality Issue

Skidmore & Turner (1989) discuss methods of modelling error accumulation, or uncertainty interval, in an effort to quantify and understand some of the effects of error. (Refer to Section 3.2.2.3 of this chapter.) The methods for trying to quantify error in a raster data set include the use of an error matrix. In this method a statistical sample is taken of the image based on a random sample selection. The binomial distribution theory is recommended for choosing the number of samples to give an estimated accuracy. There is a tradeoff between cost (number of samples taken), and confidence levels. The line intersect sampling method tries to estimate the errors introduced in the creation of boundaries of polygons. A line is drawn transecting various boundaries. The transects are checked for correct spatial location. Error bands define the fuzziness and uncertainty around a polygon.

Another method is the use of reliability diagrams for each layer. This method shows the maps make-up history or pedigree. The errors in the sources would be brought along into any subsequent derived layers. This attempts to try to estimate the errors that occur upon overlaying. Probability theory and the concept of a centrally known point and its position are two of the methods used for estimating error.

3.5.5 Environmental Decision Support System (EDSS)

Guariso (p. 9, 1989) believes that the EDSS is the next step in GIS development. An EDSS would be an open system, containing the possibility of learning on the part of both the system and the human user. A EDSS architecture should enable developments in several directions. It would not be an obstacle to changing the structure of an organization.

A general definition of DSS is an interactive computer-based system that helps decision makers to utilize data and models in the solution of unstructured problems.

A DSS should:

- assist in decisions for unstructured tasks,
- support and enhance (not replace) managerial judgement,
- improve effectiveness of decision making. It should allow more weight to be placed on making the correct decision as opposed to making a decision quicker.
- combine the use of models with the data access functions,

- emphasize flexibility and adaptability to allow change in the context of the decision making process,
- focus on interactive use (GUI).

Additional lower priority capabilities include:
- enabling an intuitive approach towards a solution,
- helping in tentative procedures as they could be supported by fast prototyping environments,
- trial and error procedures.

3.5.6 Standards

The establishment of standards for GIS data is a point of contention and a problem area. Marini (1989) says that interface format standards are difficult to achieve presently. GIS to GIS transfers usually lose topological relationships. Two standard formats being considered are DLG (Digital Line Graph) and NTF (British National Transfer Format). (See Marini for a further explanation of these formats.)

Guptill (1988) says that national clearing houses of information data sets and the establishment of standards can help reduce the costs of data entry. This will then cease to become the major cost of implementing a GIS. He goes on in his URA definition to say that standards enhance integration internally with the coordination of data, software, and hardware to optimize efficiency, effectiveness, and economy.

Zarzucki & Jiwani (1987) say there is a need for the integration and dissemination of geographic data. Therefore, a standard is needed for this information exchange. Telecommunications can be used to provide a standard for communications. This standard is called MDIF (Map Data Interchange Format). This can possibly be used for spatial data standards in GIS.

Luscombe & Allen (1989) have similar concerns regarding standards. There is a need for standards to be set for the data that is collected. There will be a need to integrate various information that is in a variety of formats. Since the World Bank is interested in sustainable development it encourages the creation of standardized information on resources in order to assist long term planning.

3.6 Concluding Comments

The potential advantages of using GIS are in the following areas. A GIS is particularly strong in data management of large amounts of data. The topological ability of GIS, or the capability of relating different data within the system is a benefit. The manipulative ability of the GIS allows modelling and 'what-if' analysis to be performed and predictions to be made. The interrelational capabilities allow the integration of different data, systems and organizations. This allows for consistent data for use in a monitoring process. Extensive and scientifically sound monitoring should help improve the modelling process. Finally the ability to output visual products, not just numeric charts and tables enhances the information exchange process between organizations using the GIS for a particular project.

The needs of the developing world to help initiate their resource management can be addressed using a GIS. The GIS has a strength in data management. As mentioned in Section 3.4.2 of this chapter, the developing world will rely on GIS. But in the developed world, data management is not the only concern. All of the potential GIS advantages can be realized. Unfortunately, not all can be practically realized by GIS users because of the cost involved in implementing a GIS. A focus is required to determine which advantage would be most beneficial for potential GIS users. This is the focus of the study described in the following three chapters.

CHAPTER FOUR - RESEARCH DESIGN

4.1. Concept and hypothesis

Initially projects are bounded by a great many constraints. The environment is one of the prevalent constraints affecting project plans. There is an opportunity to improve project planning, specifically by streamlining the process of obtaining environmental information and using the information more efficiently and effectively in the project planning and design process. The question is how to use the information. To test the hypothesis there was a need to determine if the literature in the area showed a preponderance of uses for a GIS in EIA preparation. There was a need to determine the extent to which a GIS was used in the EIA preparation process. Also there was a need to determine the expectations of people involved in the process in terms of what a system should be able to do for them.

4.2. Expected Result

The library services of The University of Calgary, Esso Resources Research Center, Department of Geomatics Engineering were accessed for determining the expected results. The research was kept current by accessing CD-ROM information on GIS developments in current journals.

From the concluding comments in Chapters Two and Three, and the use of and exposure to three environmental impact assessment reports (Cluff Lake, Caroline, Syncrude), various preliminary results were obtained for this thesis directing the research to determine which areas of the EIA process would be most receptive to improvement using a GIS. The literature indicated that there were five areas of potential use. A GIS could be used in the:

1. Storage of data and the management of the information database used,
2. Presentation of the results of the analysis,
3. Conceptual planning or scoping process to determine exactly where there should be effort placed in the EIA in terms of project management,
4. Running of modeling programs,
5. Monitoring process after the project is constructed and facilities were operating.

4.3. Assumptions

The primary system assumption was that there were areas that could be identified as being very receptive to being systematized. In other words there was a sufficient repetition of functions, within one EIA preparation, or a series of EIA preparations, that would warrant; a degree of standardization, a measurement of results, a comparison of results, and a requirement for feedback. This led to the hypothesis that a GIS, one in which the objects, entities, and data were organized and accessed by way of geographic location, was the proper and natural method by which to organize information that was used in an environmental analysis.

A second assumption dealt with the source of the information. Three areas of expert knowledge information were necessary to be researched. The first knowledge area or group accessed were project proponents. These were organizations that were interested in building an industrial project. Secondly, the legislators and the government departments involved in the stewardship of the environment were approached. They would theoretically have close access to the industries involved, and set the guidelines by which to monitor the environment and the proposed projects. Thirdly, the environmental consultants and the GIS tool suppliers were accessed to determine their knowledge base as to the practicality of using the GIS tool in the preparation of EIA's.

4.4. Limitations (Geographic and Political)

A major limitation was that a statistically significant sample was difficult to obtain, due to the lack of examples in the area of applying GIS to prepare EIA's. This suggested that there were going to be relatively few people in North America with significant expertise and experience in both the areas of EIA preparation, and with experience in manipulating GIS.

The second limitation of the study was a lack of resources. Expertise was sought within North America. A further limitation was that there was no attempt made in contacting proponents or consultants within the United States. It was assumed that the federal organization, known as the Environmental Protection Agency (EPA) would have current information as to the state of the art use of the GIS tool for the preparation of EIA's. In Canada all three respondent groups were accessed.

4.5. Method

Upon completion of the literature search, an interview questionnaire was prepared. The results of this interview process was a compilation of answers and a preparation of a survey questionnaire for additional quantitative data in support of the hypothesis.

4.5.1 Interviews

Respondents for the interview questions were obtained from a variety of sources. The respondents queried and those that responded to either or both the interview and survey are listed in Appendix C. Initially the academic sources at The University of Calgary were accessed. These were from the departments of Geography, Geology, Geomatics Engineering, Civil Engineering, and Management. Through a process of grandfather, or secondary source research, a list was compiled of contacts in government departments, consultants, suppliers, and industrial project proponents. The people were contacted by phone. If they were involved in the process of either EIA preparation or were experts in the use of GIS, and had done work in helping prepare EIA's, the interview proceeded. After an initial phone contact the respondent was either mailed the questions or faxed a copy of them. After an appropriate wait, ranging from 1-5 days, the respondents were again telephoned and the interview proceeded.

Ideally the people contacted, if they were experts in this area, would have been approached to write a paper on the subject of using GIS to help prepare EIA's. Unfortunately, this was not practical. A structure was required to facilitate obtaining information from these people. The structure took the form of questions. The questions that would have to be answered to write a paper on this subject were created in order to focus attention on the areas that should be concentrated on in standardizing an EIA for the purpose of potentially systematizing the EIA preparation process.

The investigation into the EIA process tried to identify patterns in the procedures used by people who prepared and requested EIA's. If there were areas that all proponents felt were important and always done in all EIA preparations, then this would be a prime area of concentration for further research and future work. There was an attempt made to learn what each respondent's role was in the process of preparing and reviewing EIA's. This indicated the degree of activity that was taking place in that part of the EIA preparation.

Some respondents were assumed to not be involved in the entire process from concept to abandonment of a project. The philosophical approach taken in initiating work on the EIA was determined in order to help determine the receptiveness of the respondents to new methods of preparing EIA's. This also would help focus the respondents on the theoretical goal of EIA, that of sustainable development. There were questions as to the time taken and cost of preparing EIA's. This defined the resources available for the use of any new tool. The decision support provided by EIA preparation for the project was investigated. This determined how closely integrated the EIA process was to the overall design and subsequent operation of the project's facilities. If the process was more closely integrated with engineering design, construction, and operations, then there was a possibility that more resources could be brought to bear on the EIA preparation tasks. Finally there was an attempt to determine which EIA tasks can be improved or required streamlining. This would result in the identification of opportunities for a new tool to be introduced, and a specific task would have been identified for the GIS.

The interview questions also investigated the GIS field. Since there are a wide variety of GIS products available there was seen to be a need to identify product preferences if any were to be found. There was a preliminary indication from the literature that the GIS products available usually were found to perform superiorily to competitive products in certain areas and functions. Certain products were particularly suited to certain tasks or applications and were the industry leaders in those areas. But in other areas a particular GIS was not at all the best tool available. The use to which the GIS tool was put was investigated along with future plans for the use of the tool. A variety of potential uses were discovered or gleaned from the literature search. The potential uses of the GIS needed a ranking. This determined the most acceptable use of the tool. Finally, a determination of the user's training requirements for the preparation of EIA's and the expertise in GIS use needed to be made. This strongly indicated the level to which any applied research would benefit the potential users of the tool and the preparers of EIA's. For a detailed listing and explanation of the interview questions refer to Appendix C.

4.5.2 Analysis of Interviews

The analysis of the interview questionnaire results was an ad hoc exercise. All the respondents comments were gathered by question and combined to form a single synthesized answer to the question. The answers indicated that more thorough research would determine the preferences that the users, preparers, and reviewers of EIA's have in streamlining the EIA process. These preferences needed further definition and clarification. This was done by way of a numeric survey, with an ordinal scale of measurement.

4.5.3 Survey Questionnaire

The questions on the survey closely followed those in the interviewing process. The major difference was the provision of answers, or options, for respondents to choose from. This approach made it easier for respondents to answer the questions. The multiple choice answers for the questions were taken from two sources. The first was the literature search, the second was the results of the interview process. As well, several iterations of question design and testing was done using various academic sources, and test results from preliminary respondents. Example questionnaires were tested, and various graduate students tested the survey.

The survey multiple choice answers were derived from the results of the literature search. The entire EIA process was broken down into component activities. These are the activities listed in question one of the Survey Questions (see Appendix D). The intent of question one was to describe the EIA process as comprehensively as possible, allowing respondents to decide upon the priority activities. Question two continued to describe the EIA process as a series of conceptual and detailed steps. Chapter Two of this thesis along with Appendix A listed some of the procedures and methods used to gather information and organize it in the process of preparing an EIA. Question three regarding the philosophy behind the preparation of EIA's was derived from Holling's work. Question five investigating decision support was derived from the sections of Chapter Two describing decision making and from general knowledge of engineering and operations.

The GIS list of question six was a results of the interview question responses and business research into the commercial GIS products available. Question seven investigated the expected results. The areas of modeling and research and assessment were investigated. Research and Planning and the communication of results were also investigated as areas of potential use of GIS in the EIA process. These uses were also derived from Chapter Three: (Sections: 3.4 Advantages , 3.5 Future Steps, and 3.6 Concluding Comments.) Question eight draws from the conceptual and detailed steps of question two. Question nine returns the answers in question two. The goal is to use the strengths of GIS to support the EIA process in the areas of difficulty. Question ten analyzes the implementation issues discussed in Section 3.3.

The questionnaire itself is found in Appendix D. The survey list of respondents was augmented from the initial interview list that did not answer or were not approached to answer the interview. The interview respondents provided referrals; the telephone book, industry contacts and the EPA-Washington office, provided additional contacts. In the case of the survey, the respondents were again contacted by telephone and a survey was faxed or mailed to them. After an appropriate wait, they were telephoned again to remind them of the survey. Surveys were returned either by fax or by mail.

4.5.4 Theoretical background

This interview and survey process was an abbreviated Delphi study. Abbreviated because not all the respondents that were part of the survey would agree to take part in an additional round of questions. The Delphi had been developed formally in recent times by the Rand Corporation and has been used in the past for technological forecasting. According to Linstone & Turoff, (1975):

> "(delphi) has been used in many other contexts in which judgmental information is indispensable."

In all Delphi investigations there is a common thread underlying the studies. According to Linstone & Turoff (p. 3, 1975), Delphi is a structured group communication process. The structure takes the form of the following activities:

First there is a feedback of individual's responses and knowledge.
Second there is an assessment of the group response.
Third there is an opportunity for the respondents to revise their views.
Fourth there is a degree of anonymity for respondents.

In the case of this study, a further explanation of the theoretical justification for using a Delphi is given by the philosopher Kant. He expounded what Linstone & Turoff (p. 19, 1975) called the Kantian inquiry system. In this inquiry system, real world data and theory co-exist to form an answer to a question. In this study's case, an information system development directed towards the use of GIS in the preparation of EIA's. The Kantian approach is strong in trying to deal with the future by obtaining as many perspectives on the nature of the problem as possible (Linstone & Turoff, p. 27, 1975). It is also best suited in dealing with problems that are inherently ill-structured.

4.6 Analysis of Results

The results of the survey were analyzed in two ways:

1. Ordinal Rankings Analysis.
2. Statistical Analysis.

4.6.1 Ordinal Rankings Analysis

Upon collection of the results of the survey, the rankings were collected in a computer spreadsheet. These results were analyzed in two ways to determine respondent's preferences to the options they assessed. The ordinal ranking allowed the preferences of the respondents to be analyzed using an elimination method (Cook & Kress, 1992). Specifically, the "Run-off from the top" method was used. In this method, the number of first place votes received by a response, was used to rank the preferred order of the response answers.

All the questions whose responses could be ranked, were organized into sections, and a preferred response within a section was chosen using the tests discussed below. For instance, question one of the survey is split into five sections: strategic, external, environmental, planning and management, technical. Each of these sections has from 3 to 12 possible responses that can be ranked. In this first method, the preferred response was clearly indicated numerically in the results. A second most preferred response was also noted.

A second non-parametric, distribution free method was used to analyze the data. This method used the SPSS statistical package and ran a Wilcoxon signed-rank test on the ordinal ranked data. The results compared pairs of responses to determine which response was the preferred one within a group of possible responses to a question. The Wilcoxon method tests every possible pairing of responses and determines and ranks the differences. The output of the test indicates the number of cases of one of the pair ranking less than the other, and of one of the pair ranking more than the other (see Fig.4.1). When all the pair tests are compared, one response has been preferably ranked. When compared to the other responses in the tests, the preferred response had fewer less than response ranks, and more greater than response ranks. In addition the Wilcoxon test in SPSS also calculated a 2-tailed probability, assuming a normal distribution. This statistic tried to determine the confidence with which one could say that one response was preferred over another.

```
          Wilcoxon Matched-Pairs Signed-Ranks Test

          VAR3
with      VAR4

     Mean Rank          Cases

        9.63            4  - Ranks (VAR4 LT VAR3)
        5.83            9  + Ranks (VAR4 GT VAR3)
                        11   Ties  (VAR4 EQ VAR3)
                        24   Total

        Z =   -.4892       2-Tailed P =  .6247
```

Figure 4.1 Wilcoxon tests for question 2a) a) and b).

For instance, Figure 4.1 shows the output from a Wilcoxon signed rank test. In this case var 3 has nine cases where var 4 ranks higher. In four cases, var 3 ranks higher than var 4. The significance level associated with this test is 0.62 as indicated by the two-tailed probability number. Therefore, there is a 38% chance that there is a difference between var 3 and var 4. In this case, this is not significant, the null hypothesis of no difference between these two variables is not rejected. An optimal case would have no ties in the ranking, either the greater than or less than ranks would have all the cases. Using Figure 4.1, all 24 cases would have var 3 ranked less than var 4. The Z score would be less than -4, and the 2 tailed probability would be 0. Var 3 would be the preferred response. (Refer to Appendix D to note that the preferred answers were given lower numeric scores.)

Statistical Analysis

In order to calculate statistics for the survey results, the following factors were taken into account. First, the population that answered the survey was assumed to be normally distributed. Second, the sample size gathered is small, which means the standard deviation is not an accurate estimate of the standard deviation of the population. To compensate for the small sample size the t-test was used (Rowntree, 1981). The responses were grouped as in the survey, and paired samples tests were made on all of the possible pairs in the answer group in order to determine two things. First, the statistical preferred response within the group was calculated using the calculated means. Second, the probability that the sample means are significantly different within a pair was calculated, actually indicating a preferred response. The data was entered into the SPSS software package on an Apple Macintosh computer in order to compute the statistics.

Variable	Number of Cases	Mean	Standard Deviation	Standard Error
VAR3	24	2.5000	1.351	.276
VAR4	24	2.6250	1.345	.275

(Difference) Mean	Standard Deviation	Standard Error	Corr.	2-tail Prob.	t Value	Degrees of Freedom	2-tail Prob.
-.1250	1.191	.243	.610	.002	-.51	23	.612

Figure 4.2 T-test for question 2a) a) and b).

Figure 4.2 gives an example of the output from a t-test done comparing the responses in Question 2, part a): a) and b). Response var 3 has a mean lower than var 4. Therefore, in this test var 3 is the preferred response. The 2-tailed probability represents the probability that the difference is large enough between the means of var 3 and var 4, to indicate a preferred response. In this case, that probability is 0.612. Therefore, the probability that the mean of the sample is var 3 but less than var 4 is 1 - 0.612 = 0.388, which in this case is evidence indicating a weak preference for var 3 over var 4. All responses in a section were compared in every possible pair combination. The lowest mean indicated the preferred response. The pair test giving the highest 2-tailed probability indicated the confidence in concluding that the lowest mean response was preferred. If that probability was less than 0.5 then the response with the second lowest mean was also noted. Optimally there would be a large difference between the two variable's means. Also the 2 tailed probability would be close to 0, indicating that there is a difference in their rankings. The variable with the lower ranking would be the preferred response.

CHAPTER FIVE - RESULTS

5.1. Summary

Appendix C lists the personnel that were approached in this study. They were interviewed and surveyed during the last quarter of 1992 and the first two months of 1993. The respondents were part of five separate groups: software developers, industrial project proponents, regulatory bodies, environmental engineering consultants, and academics. The regulatory bodies were accessed throughout North America. Environmental Engineering consultants were accessed throughout Canada. The remaining three groups were accessed in Western Canada. There is a predominance of Calgarian and Albertan organizations represented in this study. A total of 14 people responded to the interview process, 28 responded to the survey process.

This chapter describes the results of the information gathered through interviews, and list a summary of the information collected in the survey process. It also contains the results of the numeric ranking of the respondents for the multiple choice, ordinal scale ranked questions. The actual rankings are in Appendix D, but the preferred responses are listed in this chapter.

5.2. Results

Overall interview results

1. What is the scope of your involvement in the preparation of EIA's?

The interview respondents were from government departments, proponent organizations, research organizations, academia, consulting companies. Their involvement in the EIA process ranged from setting policy and regulations, gathering data for the EIA baselines, preparing the entire EIA, applying technology to enhance the process, evaluating the EIA process, research for the purpose of improving EIA's.

a) What is your past involvement in the EIA process?

b) Has this changed recently?

Recent changes in the activities of the people included expansion of the tool sets and the changing of legislation. In Alberta, Bill 23, The Environmental Protection and Enhancement Act was prepared. This changed the way assessments will be prepared in the future. The federal EARP process is also being, or has been changed.

2. When does your organization come into contact with preparing or assessing an EIA? During the entire EIA life cycle, what portion involves your organization?

The respondents covered the spectrum in terms of their involvement in phases of the EIA process. They were involved at the conceptual, planning stage and throughout the process to planning for mitigation and reclamation. Some of the respondents were involved in providing detailed, specific products, such as models and modeling techniques, and database management. Academics were involved in the educational case study use of EIA's.

a) Describe as fully as possible, the general EIA management procedures and methods you use. (In the areas of: data presentation, modeling, statistical analysis, data management, etc.)

The general EIA management procedures used by foresters from Ontario, for instance, was a sequence of steps in a routine EIA preparation for forest harvest projects. The basic scenario is one of understanding the project (in the case of a timber cutting plan). After project proposal a site investigation commenced, with field work and research into existing data files. This is followed with a generation of alternatives, the running of models to assess the alternatives and a review against the mandate of the department. Authorization of the project is accompanied with mitigation and/or reclamation plans. Much of this process has been defined as acceptable through existing regulations. The other respondents indicated a management and planning process through the use of regulations and government guidelines.

b) Describe the conceptual steps taken in producing an EIA i) What general data is required for these steps?

The general data required are project specific and dependent on the project location. Guidelines are followed from government departments and data is provided by some government departments. Data gathering is integrated into the entire EIA preparation process. The issue identification and scoping process conceptually determines the data requirements. The data is assembled and its form helps determine the method of its analysis. One of the products of the EIA document, the mitigation measures and monitoring process, is somewhat dependent on the data assembled. If it is easy to obtain data, monitoring that data continually should not pose a problem or incur a great expense.

ii) What information is produced from the data?

The data assembled is turned into assessment information usually in a manner set out by government guidelines and regulations. It is very dependent upon the project. A hypothesis is defined from basic project activities. It is tested by gathering evidence and data in support or in dis-proval of the hypothesis. In some cases the data gathered is handled by a system that resulted in the establishment of a mitigation activity or plan.

iii) How is the quality of the EIA verified?

The evaluation of the EIA commenced with an analysis of the assumptions and a review of the terms of reference. Political problems are probably the issue of highest concern and visibility. These have to be assessed first to determine if they are dealt with in the EIA. The next most visible aspect of the EIA to be evaluated is its scientific soundness, and the technical process design description for the project. After the fact evaluation by way of monitoring was also mentioned. A peer review, with different levels of evaluators, from specialists in specific areas to general managers of the entire process was a valid evaluative process. The scientific review could include a verification of field work. There is in some cases an assessment of the probability of error in the data collection and analysis. In general a determination is made as to whether the study encompasses the important issues and allows the next step, project authorization to proceed. A clear, concise, succinct report is of great benefit in this regard. The EIA goes through an iterative process in its being reviewed by a large team of experts throughout its preparation stages. This ensures participation, peer review, and the correct focus.

3. What is your organization's philosophy in conducting an EIA?

The philosophy by which EIA preparation occurred stemmed from that of practical sustainable development. Participation with proponents was also seen as part of that philosophy. The following of government guidelines was also seen as a philosophy of sorts. Along the lines of sustainable development were; the following of a scientific approach to analysis and prediction, the concept of integrated resource management, a preventative approach, and erring on the side of the environment.

a) What are the internal benefits to the EIA in the project's planning stage?

More comprehensive planning was most often cited as a benefit. The establishment of a level playing field for proponents was a benefit. Public participation tried to ensure a proper management of the public's expectations. Finally mitigation measures could be planned and cost estimated. Risk factors could also be identified and in some cases quantified.

4. What does the EIA process cost as a % of total project costs?

Generally the cost of an EIA falls between 0.1-3% of project costs.

a) How long does it take to perform an EIA and how is this estimated?

For some projects that are of a recurring nature, there are specific schedules for the preparation of regular EIA's. In most non-regular projects the schedule is situationally dependent.

5. Does the EIA improve the way the projects are managed? a) Does it provide the project decision support that it is intended to provide?

Overall respondents thought that EIA did improve project management. It could however provide better decision support by way of reducing government bureaucratic record keeping. The EIA is subject to the variables of a good staff and a good knowledge, or information base. It can flag contentious areas for in depth analysis. The government regulations were not seen as helping support a proponent's decisions. The proponent that has a good track record will always have his projects approved because a good EIA preparation team is proactive in dealing with the issues the organization usually uncovers. Site selection was the decision supported by most respondents. Engineering and operations were supported to a lesser degree. EIA helps screen expensive areas of analysis. In the case of timber management it helps plan operations, mitigation, and reclamation.

b) Does it streamline the project approval process?

c) If not, why does it hinder the project approval process?

If the EIA is not done properly or according to guidelines and regulations, it will result in a project delay. In a strict, short term business sense, and from a financing point of view, it can cause project delay and in some cases abandonment if the issues are not dealt with properly in the EIA. The public participation portion of the EIA does not streamline the process. In the long term outlook of the project, proper up front planning can help select the appropriate construction and operational techniques for low impact, less reclamation and the least overall life time project costs.

6. Return to question 2 a) Do you have any suggestions for their improvement if they need improvement at all? b) How do you rank these procedures in terms of the execution problems they have? c) How should these execution problems be addressed and solved?

There is an opportunity for improvement by way of an analysis of past project histories. A further standardization of techniques and the use of objective methods would also improve the EIA product. If the EIA took on a broader focus, this would also benefit the end result and the long term project success in terms of efficient operations and low impact. The process must also be made more efficient, costs must decrease, there are less people to do the work and review projects. A formal screening process would be of benefit and the establishment of accountability on various participants in the EIA preparation process should enhance the quality of the EIA product. Along the lines of better historical record keeping, is the understanding of what mitigation procedures are most effective.

7. What are the capabilities of a GIS?

Most respondents agreed with the Burrough definition of a GIS. One third of the respondents were unfamiliar with GIS. Those most familiar with it saw a spatially referenced tool. Its main advantage was database management and speed of results once the data was gathered. As well the ease with which maps could be manipulated was a definite advantage.

8. Which GIS products commercially available are you aware of?

Respondents were aware of a great many GIS products. Arc/Info, Spans, Pamap, Terrasoft were mentioned most often.

9. a) What is a GIS used for in your organization?

Map presentation was most often mentioned as a use of GIS. Database management, public presentation was also mentioned. The use in analysis and site selection, what-if modeling, integration and decision support were mentioned by one respondent. The GIS was used in research and specialty uses, especially in academia.

b) How do you see it as being used?

Respondents saw GIS as being used in the future for development and reclamation planning, public scoping, and presentations. The use of visual aides of the interactive kind offered by GIS was seen as its ideal application. Respondents expressed a preference for using GIS first for map preparation and information presentation and then for data management and integration of data sources. Modeling was the third preference.

10. What is required to improve the efficiency and effectiveness of EIA preparation?

Better effectiveness can be achieved through the use of the visual capabilities of GIS. Cost efficient modeling and integration of data sources are the next most logical improvements to make in the EIA process. An excellent data base is required for the modeling process. The effectiveness of EIA can be improved in public consultation and information exchange. A better monitoring program would benefit in evaluating the effectiveness of the EIA.

11. If you were building a decision support system, for the improvement of the EIA process, what parts of the EIA process would you see it as improving?

A decision support system was seen as improving the what-if modeling and simulation processes first. Next would be the ability to integrate with other data sources and systems, and finally to a lesser extent, the presentation of information to decision makers. Land management of the resource was seen as a potential application for a decision support system. The decision support system could be used as a crude forecaster, predicting impacts along with assessing the probability of the accuracy of the impacts. GIS was seen as an excellent screening tool and in the EIA itself to assess impacts. To a lesser extent it was seen as beneficial in use as a monitoring tool. Some of the other uses for GIS included data management, helping prepare the data for input to modeling programs, temporal comparisons, and in the use and interpretation of remotely sensed data.

12. a) What do you think the institutional impediments are to the implementation of GIS for an EIA process?

Besides a lack of GIS technical knowledge, the most common impediment is that of competing departmental mandates, overlapping jurisdictions, a fear of data corruption and loss of control. The next impediment is the past history of corporate encompassing systems and their failures in performance and not meeting cost targets. There is no corporate money for a GIS expert, the tool must be easy to use by all in order to be humanly, and economically acceptable. The cost of the system purchase and operation is another impediment, partly due to the difficulty in integrating large diverse datasets. There is also a lack of metadata.

b) What human resource skills are required?

Communications was most often cited as a human resource skill required. Teamwork, GIS skills, project management and a general knowledge of computer skills, analytical capabilities, and a familiarity of spatial operations were deemed important. Project management, environmental planning, data management were next in line for skill sets required. Geomatic skill was not essential.

c) On the basis of the answers to c), do present EIA professionals have the skill sets identified?

In general, the respondents indicated that the skill sets were present in EIA professionals. They were most deficient in GIS and geomatics training. Project management and communications were also lacking.

d) Which of the skills do you expect to be taught as "core "skills (say at University), and which do you expect to be gained through "in-career" professional development.

Core Environmental planning was most often mentioned as a core course requirement. Project management, data management, and general computer skills were important. The scientific skills in research were deemed important as a core skill.

In-Career Obtaining experience in a particular domain and geographic area was seen as beneficial. Project management, GIS business development and software training could be accomplished at this time also.

Survey Results

The following table lists the results of the three tests performed on the ordinal survey data. The non-ranked survey comments are contained in Appendix D. The t-test preferred answers have their probabilities in brackets except in the case of a tie as in Questions 8 and 9. First and second most preferred answers are noted in the chart.

Table 5.1 Results from Parametric and Non-parametric Analysis.

Question #	Description of preferred answer.	T-test results ranking	T-test results (prob)	Run-off ranking	Wilcoxon ranking
1	Environmental.	1	(.830)	1	1
Strategic	Government regulatory compliance.	1	(.875)	2	1
	Stewardship of resources.			1	
External	Public consultation management.	1	(.504)	1	1
	Facilitation of the process.			2	
Planning	The entire process from concept to abandonment.	1	(.808)	1	1
	Conceptual development.			2	
Environment	Screening process for major impacts.	1	(.463)		1
	Impact identification.	2		2	2
	Environmental baseline studies.			1	
Technical	Ground field data gathering.	1	(.672)	1	1
	Modeling/simulations.			2	
2 (a)	c) describing the project actions, alternatives, and impacts.	1	(.922)	1	1
	a) conceptual project review and planning the study strategy.			2	
	g) predicting impacts.	1	(.814)	1	1
	i) listing valued ecosystem components or impact indicators			2	
(b)	e) simulations	1	(.254)	1	1
	d) model building	2		2	2
	g) literature search	1	(.282)	1	
	i) pictorial map representations			2	
	h) CD-ROM database searches	2			1
	q) use components from different methodologies	1	(.353)	2	2
	o) use of similar projects as models	2		1	1

Table 5.1 continued...

	t) inform publics by way of:				
	ombudsman	1	(.258)	1	1
	demonstrations and field trips	2			2
3	Basic regulations.	1	(.726)	1	1
5					
Strategic	Site Selection.	1	(.106)	2	1
	Government regulations.	2		1	2
Engineering	Mitigating construction impact.	1	(.330)	1	1
	Abandonment, reclamation plans.	2		2	2
Operations	Altering operating parameters	1	(.145)	1	1
	Waste stream	2		2	2
6	Arc/Info	1	(.938)	1	1
7	a) Computer system for integration	1	(.777)	1	1
	d) what-if scenario investigation			2	
	g) Pictorial map presentations	1	(.666)	2	1
	k) overlays			1	
	n) Use of similar projects as models	1	(.370)	1	1
	o) general knowledge of project types	2			2
	q) field data collection			2	
	s) presentations	1	(.984)	1	1
	interactive workshop tool			2	
8	b) baseline study, the study of nature	1			1
	f) continual review of impacts	1		1	2
	e) preparing public hearings and presentations			2	
	j) assessing the magnitude of impacts	1	(.442)	1	1
	i) listing valued ecosystem components or impact indicators.			2	
	g) predicting impacts	2			
9	b) baseline study	1	(.946)	1	1
	e) presenting public hearing and presentations			2	
	j) assessing the magnitude of impacts	1		1	1
	g) predicting impacts	1		2	2
	s) field data collection	1	(.996)	1	1
	p) use of similar projects as models			2	
	u) presentations	1	(.999)	1	1
	demonstrations			2	
10	Environmental Planning	1	(.911)	1	1
	Geo-Informatics			2	

CHAPTER SIX - CONCLUSION

6.1. Summary

The thesis conclusions are derived from research into the literature in the EIA and GIS fields; and through the interview and survey of over 70 people involved in the EIA process, and the GIS industry. The major findings of the research, the project management improvements that could be realized in using GIS, and the suggested future work are discussed below.

6.2. Major Findings

The major findings of the research are organized into the three areas of EIA, GIS, and areas that GIS can improve EIA.

In the EIA area the interview and survey results indicated that:

- The preparers of EIA had a strong need to satisfy government regulations.
- Scientific soundness, future verification with monitoring, and an excellent presentation of the results are essential components of EIA's.
- The principle of sustainable development is an EIA's foundation.

6.2.1 Improvements

- EIA improvements could occur by broadening the scope of the study (temporally, bio-geophysically, socio-economically).
- EIA improvements could occur also in the monitoring of projects, and the collection of project histories to help provide a basis for the establishment of an accountability procedure.

6.2.2 Problem Areas

The following were problem areas in EIA preparation:

- Model use,
- Integrating and interpreting data from a large variety of disciplines and sources,
- The collection of data and the creation or collection of a good data base of pertinent information,
- Communications between parties working on the EIA,

- A lack of time and money to complete EIA's

6.2.3 GIS

There was a recognition of the value of GIS in the following areas:

- The storage of data and the management of the information data base.
- The running of modeling programs.
- The presentation of results of various analysis.
- The monitoring of existing impacts.
- The integration of diverse data sources.

Improving EIA's using GIS is potentially difficult because of the skill sets required by those preparing EIA's, and institutional impediments the individuals are subject to. The skill sets required include:

- Computer science and GIS skills,
- Communication and project management skills.

6.2.4 Institutional Impediments

- Management misunderstanding the technology.
- A lack of time to learn the use of the technology.
- The high cost of a GIS.
- A fear of the technology.
- Departmental friction and organizational data standards.

GIS could be used best as shown in Table 6.1, to address the following EIA problem areas:

- Simulation and model building of the environment and a project's impact on that environment.
- Displaying maps of the project site.
- Using similar projects as models.
- Using components from different methodologies and integrating different discipline's results.
- Presenting or informing the public of the results of the analysis.

Table 6.2 shows the EIA priority effort activities, which can be improved using GIS.

The baseline study for instance, can have its data managed using a GIS. The GIS could manage the checklist of items that government regulations place on a project.

The visualization capabilities of GIS in being able to graphically portray the map of the project site and impacts, streamlines the environmental assessment activities of screening, impact identification, prediction, and alternative generation. Streamlining occurs due to the ability to integrate information for different areas, interpret the information with modeling programs, and alter underlying assumptions more quickly than would be otherwise possible.

One particular interesting result was the use of GIS for the continual review of impacts, for monitoring the project. This potentially can help improve all of the EIA priority effort activities listed in Table 6.2. The first improvement would be in the streamlining of the activities through systematizing, integrating information sources, and presenting the results of the activities. The second improvement is in future projects and the experience gained by making the impact predictions, and being able to check them quickly using the GIS monitoring tool. The next project would have its EIA prediction improved. With an improvement of the EIA process in this manner the initial project planning and analysis steps can be streamlined. The length of time spent informing stakeholders of the environmental impacts and mitigative measures can be reduced. The cost of preparing EIA's can be reduced through the integration of large, diversely originating information. The preparation cost also can be reduced by cross organizational integration that GIS causes to occur, at which point communication is enhanced.

Table 6.1 EIA Problem Areas with GIS Solutions.

GIS Areas of Strength in the EIA Process

EIA Problem Areas	1. Preparing map representations and overlays.	2. Using similar projects as models.	3. Presenting model results.
1. Simulations and model building.		✓	
2. Literature search.			
3. Pictorial map representations.	✓		✓
4. Similar projects as models.		✓	
5. Use components from different methodologies.		✓	
6. Inform publics by way of ombudsman, field trips, demonstrations.	✓		✓

Table 6.2 EIA Effort Filled Priority Activities that GIS can Improve.

GIS Improvements for Priority Efforts

EIA Priority Efforts	1. Baseline study and the study of nature, (field data collection).	2. Listing valued ecosystem components or impact indicators.	3. Assessing the magnitude of impacts.	4. Continual review of impacts.
1. Environmental activities:				
- Screening process for major impacts.		✓	✓	✓
- Environmental baseline studies.	✓	✓		✓
- Impact identification.		✓	✓	✓
- Impact prediction.		✓	✓	✓
- Describing project actions, alternatives, and impacts.		✓	✓	✓
2. Strategic activities:				
- Government regulatory compliance.	✓	✓	✓	✓
3. Planning and Management:				
- The entire process from concept to abandonment.				✓

6.3. Future Work

GIS should be used to integrate the information gathered in preparing the baseline of the environment. The assessment of the data and the identification of the valued ecosystem components or impact indicators should also be done using GIS. Following that, the running of models using this stored data to assess and portray the impact of developments on the environment should be done using GIS. Finally, a continual review of the actual impacts and a comparison with the modeled and predicted impacts should be done using GIS. The intent of such a comparison would be to improve the prediction process of the models used in EIA impact predictions.

The thesis research indicated that EIA supports decisions in the following areas:

1. Strategic decisions:
   - Site selection.
   - Government regulations.
2. Engineering decisions:
   - Mitigating construction impact.
   - Setting abandonment and reclamation plans.
3. Operational decisions:
   - Alter operating parameters.
   - Waste stream reduction.

Satisfying governmental regulations was a major driving factor influencing EIA preparation. The survey indicated that EIA could draw upon the benefits realized in: supporting the decision areas above, better project planning, integration of diverse data sources, and avoidance or at least a reduction of conflict during the project's proposal stage. The cost of EIA was seen to be 1-5% of the total project costs. The fact that the costs were very tangible, while benefits were intangible, indicates that in order for the EIA process to improve, the main driving factor, that of government regulations, would have to intiate any change. Any successful changes would need to have a strong industry and academic collaboration. If the government proposed or indicated a favourable response to implementing the advantageous use of GIS in EIA preparation, this would encourage its use and initiate improvement in EIA such as those indicated above.

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APPENDIX A - EIA

EIA Methods

I Land Suitability analysis

1. Mcharg's overlays. Based upon spatial reference. Mcharg (1969) was the originator of the overlay method of land classification for taking environmental factors into account. The overlay method is static, expert based 'gray' scale.

2. Metropolitan Landscape planning model - extends McHarg onto computer (METLAND).

II Matrix

Munn (1979) suggests the use of a matrix to identify cause and effects relationships. The Leopold matrix was initially used. A Leopold matrix contains project actions across the top and environmental characteristics along the side. The cells contain the ranking system for the magnitude and for the importance of each impact. Contains the actions and conditions that fit in the axis.

Westman (1985) describes another matrix. Project actions are plotted against human and natural environmental elements. Separate scoring is done for magnitude (normative or evaluative) and importance (objective or empirical).

There are problems with:

- preparation time taken, difficulty in conceptualization,
- scales used and comparison problems (ratio, interval, ordinal, nominal),
- the use of grand indexes ascertain differences between two matrices.

III Checklists (Westman, 1985).

A checklist systemizes the preparation of a list of impacts. It allows concise summarization of impacts, but there are problems in incompleteness, no interaction information, double counting impacts, big lists, qualitative and subjective, and no probabilities. A sample of some of the checklists mentioned by Westman and Munn follow.

1. Environmental Evaluation System - 78 attributes, value functions.

2. Environmental Quality Assessment method (EQA) includes: ecological components, biologic category, aquatic factor, measurement (physical measurement, qualitative descriptions).

3. Water Resource Assessment Method (WRAM) - critical variables are organized into environmental, economic, social, development accounts.

4. Wetland Evaluation System (WES) - uses a mathematical impact formula.

Munn[1]. A Batelle Environmental Evaluation System, separates human concerns into categories. Each component of the category has an index of value functions that indicate at what point of proposed action the component is degraded. Also each component has a weight.

IV Network Analysis

1. Sorenson Network (Westman, p.142, 1985) for coastal zone use is an extrapolation of the land use type matrix. This matrix organizes and portrays initial conditions, causes of impacts, consequences and effects.
2. Flow diagrams allow visualization of the connection between the action and the impact.

V Simulation/Modelling

1. Kane (KSIM: Kane Simulation Model, Hyman & Stiftel, p. 198, 1988) clarifies system interrelationships by using computer analysis of resource management and impact assessment.
2. Habitat Evaluation Procedure (HEP, Hyman & Stiftel, p. 212, 1988) HEP "assesses the effects of development on a single aspect of the environment." The steps in completing a HEP are to identify habitat types, select indicator species, estimate changes in habitat types. There is an option to place a monetary value on change in wildlife populations.

3 Adaptive Environmental Assessment and Management (AEAM, Holling, 1978). Beanlands & Duinker (1983) support the Holling method.
"In a widely recognized book, Holling (1978) developed the rationale behind "Adaptive Environmental Assessment and Management." This approach is an outgrowth of a recognition of the highly dynamic nature of ecosystems and the need

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[1]Munn, R.E., ed. Environmental Impact Assessment Principles and Procedures, John Wiley & Sons, Toronto, 1979.

to have policy-makers participate in the design of resource management and impact assessment strategies. The development of a simulation model through a series of workshops involving scientists and administrators is used as an effective means for communicating and learning, as well as assisting in research planning and providing some predictive capability. The publication stressed: (i) the high natural variability of most biological phenomenon in space and time, (ii) stochastic events and the need to consider risk analysis, and (iii) the resulting futility of trying to predict changes through the inventory approach so common in impact assessment."

MacLaren & Whitney (1985) suggest the use of the AEAM approach. They use the term SOS (science of surprise). In addition:
- the major part of assessment should be the formulation of specific hypothesis of impact.
- testing the hypothesis should be the basis of the assessment.
- tradeoffs exist between minimizing risk of failure against minimizing consequences. A pilot project should limit consequences.
- "face surprise with a system that is used to it".
- set procedures to communicate interdisciplinarily.
- they assemble a core group of specialists and analysts (programmers).

The steps in the AEAM process are as follows:

i) scoping session:
- outline the problem (inputs,area,objective),
- plan workshops,
- participants.

ii) workshop issues
- objective: model to predict impacts.

Holling (1978) states that the model should be used in orchestrating the assessment by only being detailed enough to capture the essential behaviour of the system being studied. Simplification is the idea behind modelling.

Methods of simplification:

- The use of sub-models of the entire study area,
- Analytical models and the use of differential equations to simplify.
- The use of pictures and graphs. Especially for qualitative information. This shows the effect of different variables on study area and changes experienced over time.

- reality: think about the problem and the 'whole' impact,
- people split along compartments,
- bounding, quantification of objectives,
- result is a working conceptual model and a run of scenarios,
- list of information needs,
- incorporate research into model, run what-ifs.

Holling (p. 1, 1978) states "the process of adaptive environmental management and policy design, which integrates environmental with economic and social understanding at the very beginning of the design process, in a sequence of steps during the design phase and after implementation."

A small group of core experts is used for coordination. Integration of information comes from computer systems. Workshops set the research agendas and the series of steps needed to complete the analysis to make the decisions. A minimal model is required to be created by the group. The workshop should deliver the following:

- alternative generation,
- design of policies to achieve objectives,
- policy evaluation,
- communication and interaction between participants.

Techniques are chosen according to three key characteristics:

- the number of variables,
- the level and breadth of understanding of processes,
- the number and quality of the data.

Holling (p. 20, 1978) has a list of recommendations for adaptive management.

1. Environmental dimensions should be part of the initial development planning process.

2. There should be periods of intense focused effort with non-governmental organizations followed by consolidation.
3. Benefits should be incorporated into the design from the socio-economic effects known or partially known.
4. The production of information should be part of the research plan and others should be part of the management activities.
5. Design in monitoring.
6. Ensure the assessment design tries to determine the effect of ameliorating versus designing out uncertainties.

Rodger (1990) has these comments on model categories:

1. Extensive models are unbounded and comprehensive; geographically and temporally.
2. Adaptive models change as assumptions are clarified and facts become clearer, they coordinate disparate information sources.
3. Subsystem models limit the bounds of the system and reduce assumptions by depending only on physical laws.

Limitations of the systemaccording to Westman (1985):

- models can only be built concerning ecosystems with extensive data available. When data are not available then there is the option of collecting the data as the development begins operations, at which point the operations will be modified through management of the development. Model validation testing is lacking however.

VI Multiple Objective Analysis.

1. Goals achievement matrix:
   - define objectives quantitatively/qualitatively,
   - project anticipated impacts and weights.
2. Surrogate - worth tradeoff method (SWT):
   - iterative interviews,
   - complicated solution.
3. Applied decision analysis:
   - identify objective and measurement attributes,
   - predict probability of future,

- respondent expresses preference for attribute,
- optimize.

4. SAGE (Social, Adaptive, Goals achievement Environmental Assessment) is based upon social judgement theory by analyzing decisions.
   - predict effects,
   - scale attributes into accounts,
   - eliciting relative value weights that individuals or groups attach to each objective,
   - presentation.

   Field test:
   1. Five objective accounts,
   2. Two alternatives,
   3. Estimate effects,
   4. Scale attributes according to importance,
   5. Estimate weights to accounts and alternatives and determine preferences,
   6. Identify judgement types.

VII Economic Approaches

Westman (1985) states monetary units are not good measures of utility because the price of a resource does not reflect value, it only reflects the balance between supply and demand. Other problems are:

- some items have no direct market price,
- individuals value items differently.

Assumptions made:

- losers accept financial compensation,
- the full loss value is known,
- the losers know the value,
- there is no equity in the distribution of gains/losses,
- future generations may not value things similarly,
- species cannot be compensated.

In order to use market process full competition must be present. Discounting and the time value of money does not take into account the value future generations place upon the resource. The economic analysis of pollution tries to determine the benefits of lessening the damage to free goods of nature and from reducing the costs of repairing damages. Damages are difficult to measure from human activities. There are many areas that are damaged but will not or can not be accurately measured or are even unknown.

Economic surrogates are used to determine value (e.g. travel costs to parks to evaluate the park). Property values, lake front property values the lake quality. Bidding games are used and through a consensus building exercise a price is placed on the asset. Some of the resources are clearly impossible to sell, clean air for instance. It is difficult to known the structure of the ecosystems that are around. It is extremely tough to evaluate the net worth of the organisms that inhabit the ecosystem because their functions are not completely known.

Hyman and Stiftel (1988) provide examples in estimating the monetary benefits and costs of environmental quality.
Welfare economics can be used.

- utility based on hedonistic psychology,
- consumer surplus,
- decision rules Pareto, Kaldo-Hicks,
- discounting welfare over time.

Basic Concepts behind the estimations of value are the:

- principles of conservation of mass & materials,
- input - output analysis,
- option value (benefits of a resource even if not used),
- non-renewable, critical zone, renewable.

Non-survey techniques. These are techniques that do not require the canvassing of various segments of society to obtain consensus results. The costs can be estimated by experts.

- replacement costs & defensive expenditures:
  - legal and administrative expenses,
  - alternative cost (e.g.coal plant versus dam).
- related expenditures (proxy: complimentary, related goods),
- travel costs (unit day travel, expert value estimate based on use # and access),
- property value (time value of money) must include defined use of land, substitution may occur (swimming pool vs clean lake),

- wage differential labour availability or cost for contaminated zone fails for poor people,
- Human capital approach labour market valuation,
- Threshold analysis (i.e."If preservation benefits are unknown, how large would they have to be to leave you indifferent between development and preservation?" (Hyman & Stiftel, Chapter 4, 1988).

VIII Jain et al (1977) suggest an energy analysis as an alternative approach.

1. Energetics is a study of the potential use of energy of all inputs to a region.
2. Energy accounting converts resources into useable energy in a process.
3. Thermodynamics assigns limits of efficiency for a process.

There are problems with the process:

1. Single factor theory of value.
2. Treatment of time.
3. Energy quality.
4. The system boundary.

Groups indirectly affected by the industrial developments

1. Unbiased public that have no opinion.
2. Sporting groups.
3. Conservationists.
4. Farmers.
5. Potentially displaced property owners.
6. Business groups.
7. Professional groups (engineers, lawyers, construction company groups).
8. Educational institutions.
9. Service clubs.
10. Labour unions.
11. Government agencies.
12. Politicians.
13. Non Governmental Organizations.
14. Media.

<u>Methods of Communication</u>

Before listing the methods there are these suggestions for meetings:

1. KISS presentations (Keep It Simple Stupid).
2. Broad scope of project fully explained.
3. Visual aids are used extensively.
4. A schedule for the presentations is maintained.
5. Discuss relevant economics.
6. Generalists should be at the meeting, not experts who cannot communicate.
7. Sincerity must be evident.

Methods:

- public hearings,
- public meetings,
- informal small group meetings,
- general public info. meetings,
- presentations to community organizations,
- info coordination seminars,
- operating field offices,
- local planning visits,
- class action litigation,
- brochures and pamphlets,
- field trips and site visits,
- public displays,
- models,
- mass media material,
- public inquiry responses,
- press releases inviting comment,
- requests for comments,
- workshops,
- advisory committees,
- task forces,
- community residents,

- community advocates,
- ombudsman,
- EIA review by public.

APPENDIX B - GIS

Applications and Examples

CARTOGRAPHY

"Cartography deals with the conversion of spatial information into map symbolism." (Marble et al, p. 5-6, 1984)

Marble et al lists this table showing some of the spatial information on the left and the techniques used to symbolize or represent the spatial information on the right.

INFORMATION	REPRESENTATION
(geographic entities)	(map symbolism)
- spatial attributes	- spatial properties
*location in space	*location on the map
*spatial dimensions	*dimensions of symbol
punctual	point symbol
linear	line symbol
areal	area symbol
	*symbol'size (height, width)
- non-spatial attributes	- non-spatial properties
*attribute types	*type of symbolism
thematic	graphic
temporal	literal
reliability	
*measurement scale	*graphic variables
nominal	for graphic symbols:
ordinal	density of symbol,
interval/ratio	color (hue and saturation),
	shape or form,
	texture/pattern,
	orientation/direction.
	for literal symbolism:
	face or style (sans serif, serif, etc.),

form (upright, sloping),
weight (bold, etc.),
width (condensed, etc.),
case (capitals, etc.).

GIS data manipulations

Burrough (1986) and Star & Estes (1990) set out the following GIS manipulations.

1. Reclassification and Aggregation

This function is required because the original data is inappropriate for use and information categories (attributes) need to be modified. Recoding may be needed to classify data in terms that are suitable for the application.

- usually in mapping:
  - geographical info is analyzed and attributes classified,
  - a table is built for the classifications (legend),
  - spatial variations are ignored as classifications are painted on the map.
- in GIS
  - geographic information is gathered,
  - classifications are created as needed for every level of detail.

There is a change in technique in that spatial areas are fit into a classification but with a GIS all the nuances of a spatial area are saved by creating new classifications for them.

There are five typical classification methods used in GIS:

- ranges within a single continuous variable, such as elevation,
- exogenous universal, potentially lacking in detail,
- arbitrary,
- idiographic - i.e.'natural breaks',
- serial - mathematical (percentile, statistical).

- multivariate (many properties per data point) analysis & classification:
  - ordination,
  - principal component analysis,
  - averaging,
  - canonical variance analysis,
  - cluster analysis (scattergram),
  - allocating individuals to existing classes,
  - maximum likelihood classification (Bayesian algebra) e.g. according to theory.
- Rules for re-classification:

- do not classify if you have original data for further processing,
- classify if multivariate, if essential for further analysis,
- classify for display not for storage.

2. General approaches to overlays.
   - The following are classes of transformation functions:
     - point operations (e.g. +,-,x,/,etc.),
     - regional operations (renumber legend, area calculations, etc.),
     - neighbourhood classifications (e.g. shortest route).
   - logical combinations of attributes are required in order to be able to perform Boolean operations.
   - classifications start with several data layers and with a group of statistical procedures to derive a single multi-value layer. The technique locates and describes relatively homogeneous regions.
     i) With supervised classification the analyst describes classes and the system tries to put data into these classes.
     ii) With unsupervised classification, the system does the statistical analysis and groups the data. Probability assignments are determined by the system.
3. Geometric operations on Spatial Data such as registration and rectification, (Star & Estes, 1990).
4. Centroid determination of geographic areas.
5. Data structure conversion from raster to vector and back.
6. Spatial operations:
   - connectivity operations:
     object proximity (buffer creation).
     networks optimize travel corridors.
   - neighbourhood operations can be used to smooth out data (i.e. *low pass filtering*),
     - a mean filter can perform a spatial convolution using a kernel to smooth the data,
     - an edge-detecting or high pass filter (See Moik 1980 in Star and Estes),
     - a median filter removes the effect of outliers, data points not associated with the majority of the data,
     - texture transformations enhance the heterogeneity of an area,
     - a slope transformation turns elevation data into slope information,

- aspect calculation determines the direction that the slope faces,
- slope along a specified path profile or cross-section graph,
- scale change,
- distortion removal, rubber sheeting,
- projection changes,
- rotation.

Burrough (1986) - trend surface analysis

- regression analysis,
- significance as quanticized by statistics,
- Fourier series (no-periodicity).

Marble et al (1984) mention Digital Terrain analysis

- display of data,
- interpolation/contouring,
- slope/aspect/sun intensity,
- watershed computation,
- visibility/viewsheds.

7. Measurement of distances, items, direction, volume, area, perimeter, etc.

8. Statistical Analysis.
   - descriptive statistics,
   - histograms or frequency counts,
   - extreme values,
   - The ability to extract data from the GIS for analysis by a more powerful statistical package is paramount.

9. Modelling

   User needs evolve with time, becoming more intricate. There are a number of considerations in extracting data to outside systems:
   - ability to extract a specified subset of information, both spatial and attribute data.
   - ability to determine the organization and format of this information.
   - interactive query language for what-if scenarios.

Benchmark

These are a listing of the GIS capabilities that should be tested with a benchmarking exercise.

1. Graphics: series of capture and update of spatial information. Up to 40% of the required graphic functions need to be tested.
2. Characteristics of test dataset: a set of objects that have complex symbols and topology, the kind found in the user applications need to be used.
3. Human interface. A proper GUI can lower the risk of rejection, reduce training times, improve throughput in the system.
4. Performance tests
    - number of menus to be accessed for various functions,
    - time required to go from one menu to another and to perform functions on data sets of expected size,
    - how quick is the documentation in providing guidance.
5. DBMS
    - Characteristics of tests. The size of the data should be substantial, a variety of object types and relationships should be tested.
    - Functional capabilities that need testing are:
        - the capability to define and manipulate windows and access the same data in a number of different windows,
        - the capability to customize the graphics to display multiple themes,
        - an adaptive display of a variety of graphical output displays,
        - 3-D visualization capabilities,
        - determine the performance limitations of the macro shell,
        - display of the menus on the screen,
        - default parameters,
        - hardware required in terms of screens,
        - function key assignment,
        - use defined object display,
        - computer language,
        - units,

- an overview of the system to familiarize the user with the model being built,
- documentation:
  - *data modelling - Can the most complex model available be used?
  - *data base design - How are the tables and keys programmed?
  - *security - What are: the restrictions on access of data, warnings given to users, legal restrictions. How are user groups defined and backups of data managed by the system?.
  - *multi-user - How are simultaneous access requests handled?
  - *flexibility - Determine the time taken and the steps involved in order to change the data by:
    - - adding a new class of objects,
    - - adding attributes to an existing class,
    - - deleting an existing class with relationships,
    - - deleting an attribute.
  - *self configuring - Can the building of the first data model have its information used in the building of subsequent data models?
  - *Query language - SQL (System Query Language). Does the SQL:
    - - extend spatial reference operators,
    - - combine attribute and spatial query in one statement,
    - - have distinct selection and output operations,
    - - save SQL queries,
    - - have transparent physical data distribution locations,
    - - Does it have a form driven query environment?

- Performance tests are to be performed on three sizes of data sets. The data sets should be bigger than the RAM of the hardware used. The test should record the time taken.

  *Attribute tests search for indexed and non-indexed attributes.

  *Spatial query tests search for all occurrences of an attribute in a given window.

  *Combined attribute and spatial query tests should be performed.

  *Data extraction tests for the use of data externally or in a distributed environment need to be completed.

APPENDIX C - INTERVIEW QUESTIONS

There are twelve questions in the interview. They explored both the EIA and the GIS areas of organizational involvement. They also explored the opinions on potential involvement.

QUESTIONS AND THEIR EXPLANATION

1. What is the scope of your involvement in the preparation of EIA's?
a) What is your past involvement in the EIA process?
b) Has this changed recently?

The first question was designed to determine the organization's involvement in the EIA preparation. It was assumed that not all respondents would be preparing all portions of an EIA all the time. As well their current activity might be different that their past and planned future activity.

2. When does your organization come into contact with preparing or assessing an EIA? During the entire EIA life cycle, what portion involves your organization?
a) Describe as fully as possible, the general EIA management procedures and methods you use. (In the areas of: , data presentation, modeling, statistical analysis, data management, etc.)
b) Describe the conceptual steps taken in producing an EIA i) What general data is required for these steps?
ii) What information is produced from the data?
iii) How is the quality of the EIA verified?

The second question further explored the organization's scope of EIA involvement. It tried to determine a pattern of steps used to prepare EIA's. If a certain activity was being completed by respondents on a regular basis, it could potentially be a candidate for a systemization. Part a) of the question tried to determine general EIA procedures used. Part b) wanted a sketch of a conceptual action plan in preparing an EIA.

3. What is your organization's philosophy in conducting an EIA?
a) What are the internal benefits to the EIA in the project's planning stage?

The third question tried to determine the driving forces behind an EIA preparation. Answers theoretically would indicate areas in which a preference was indicated in preparing an EIA. Part a) of the question tried to link the EIA process to overall project planning. It tried to determine the degree of integration that took place between the EIA and project planning and engineering.

4. What does the EIA process cost as a % of total project costs?
a) How long does it take to perform an EIA and how is this estimated?

Question four tried to determine the amount of money available in an EIA and the amount of time taken for an EIA preparation. This gives an indication of whether or not a pilot project using GIS to help prepare an EIA is feasible given a typical EIA project.

5. Does the EIA improve the way the projects are managed? a) Does it provide the project decision support that it is intended to provide?
b) What types of decisions does it support? (i.e. site selection, setting engineering design criteria, altering operating parameters.)
c) Does it streamline the project approval process?
d) If not, why does it hinder the project approval process?

Question five delves further into the issue of realizing benefits of performing an EIA. It tries to determine the degree to which EIA information is integrated or drives project planning decisions. It tries to determine if the EIA was seen as being detrimental in planning a project, or whether the information gathered was seen as forming barriers for designers or opportunities to improve design.

6. Return to question 2
a) Do you have any suggestions for their improvement if they need improvement at all?
b) How do you rank these procedures in terms of the execution problems they have?
c) How should these execution problems be addressed and solved?

The sixth questiòn asks respondents to improve their method of preparing EIA's. If there are a number of different areas that require improvement, respondents were asked which area or procedure would have priority.

7.What are the capabilities of a GIS?

Many of the respondents familiar with EIA preparation were assumed conservatively not to have exceptional expertise in using GIS. The seventh question defined GIS and generally described the capabilities of GIS.

8. Which GIS products commercially available are you aware of?

The eighth question determined which GIS were being used by respondents.

9. What is a GIS used for in your organization?
How do you see it as being used?
- A decision support system for improving the EIA process.
- The preparation of maps for the EIA
- What-if modeling/simulation scenarios
- the integration of data sources
- the building of models

This question tries to link the GIS's mentioned in question eight, with uses for the GIS in the environmental arena.

10. What is required to improve the efficiency and effectiveness of EIA preparation?
a) If you were building a decision support system, for the improvement of the EIA process, what parts of the EIA process would you see it as improving?
- what-if modeling and simulation processes,
- the ability to integrate with other data sources and systems,
- the preparation of maps and the presentation of information to decision makers.

Question ten continues investigating the direct use of a system to improve EIA preparation. The options listed in the question were derived from the strengths of GIS and areas in which EIA could be improved. In this question the respondent is asked to fit the EIA to the GIS capabilities.

11. Where do you see GIS fitting into the scheme of EIA preparation most effectively?
___ In the screening process,
___ In the pre-feasibility assessment,
___ In the EIA itself,
___ As a monitoring tool,
___ Other...

Question eleven further explores where GIS would fit into the creation of a DSS to help prepare EIA's. In this case the areas of the EIA are listed and the respondent is asked to decide which area would be best suited to use a GIS tool to help in its completion.

12. Given that GIS can be used to enhance the EIA process, there may be human resource and institutional impediments to the implementation of GIS for an EIA process.
a)What do you think the institutional impediments are to the implementation of GIS for an EIA process?
b) What human resource skills are required?
d) On the basis of the answers to c), do present EIA professionals have the skill sets identified?
e) Which of the skills do you expect to be taught as core skills (say at University), and which do you expect to be gained through "in-career" professional development. Core, In-Career

The final question deals with the human resource issues. This question was suggested by the Banff School of Management. They provided advice as to the construction of the interview questions and requested the inclusion of this question. It was designed to indicate the additional training costs associated with the use of GIS. Also it tries to determine the degree to which there are available GIS professionals or EIA professionals with GIS expertise.

Respondents Contacted

LOCATIONS & PEOPLE:

Academics

- Professors at The University of Calgary:
    - Mike Chapman (Geomatics)
    - Rongxing Li (Geomatics)
    - Ian Crain (Geomatics)
    - Michael Coulson (Geography)
    - William Ross (Environmental Design)
    - Alan Kennedy (Graduate Studies/ERCL)
    - Richard Revel (Environmental Design)
- David A. Gauthier (U of Regina), (306) 585-4154 (fax) (306) 585-4815
- Milne Dick (U of Saskatchewan) Hydrology Institute (306) 975-5730
- Jim Beck (U of Alberta Forestry) (403) 492-2356

Regulators

- Environment Canada
    - Maureen Moffat (819) 997-3352 Ottawa.
    - Kent Hamilton (613) 951-8585
    - Ed Wiken (Ecology)
    - J.P. AuClair
    - Richard Baker (819) 953-1693
    - Roger Percy (Halifax) (902)426-2576 (902) 426-9709
    - Bob Boulden (819) 953-1690
    - Roger Albright (902) 426-4480
    - Geoff Howell (902) 426-4480
- Roger Creasy (ERCB)
- Alberta Forestry, Lands & Wildlife
    - Jeff Bondi (403) 427-3582
    - Lanny Colson (403) 427-3608
- Alberta Environment contacts:- Bob Stone, Bonnie Magill
    - Cam Magregor 422-9615, (fax) 422-3578
    - John King 427-6202

- Frank Kloiber 427-5200
- Jarry Brocke (reclamation) 422-2636

- Alberta Forestry, Lands & Wildlife- Jennifer Steber (spans) (403) 427-3608
  - Harry Stelfox 427-6750
  - Rick Hegg
  - Della Clish 427-6729
- Andrey Litviak (Alberta Geologic Survey) (403) 438-7608
- Ron Kervin (Guelph) Ministry of Natural Resources (705) 642-3222
- Dan Marining Ministry of Natural Resources, Ontario (705) 642-3222
- EPA Washington DC - Jeff Booth (National GIS office) (703) 557-3088
  - Chuck Carpenter (OSWER Superfund) (202) 260-6754
  - David West (Region 3) (215) 597-1198 (fax) 597-7906
  - Carol Langston Dallas (214) 655-2263
  - David West (Region 3)
  - Heinz Mueller (404)347-3776
  - Walt Foster (913) 551-7290
  - Greg Charest (617) 565-4528
- Phil Hall (Bureau of Land Management, Oregon) (503) 440-4930

Proponents

- James Mitchell (Nova) 290-7373
- Rick Bonner (Weldwood) Hinton 865-2251
- Kevin Hogan (Shell) Dave Hagopian, Doug Mead
- Ron Goodman (ERCL)

Environmental Consultants

- Russell Morrison (Delta) 269-5150
- Bill MacKenzie + Ed Roger (Projection Mapping)
- Ron Wallace (Dominion)
- Jim Case (Case Biotechnologies)
- Richard Rowell (Concord) 264-2140
- David Foster CGIA (919)733-4984
- Al Levinsohn (Levinsohn Consulting) (403) 678-4591
- Bob Everitt (ESSA) Vancouver (604) 733-2996

- Frank Kloiber (Government of Alberta, Department of Energy) 427-5200
- Dave Charlton Ecological Services for Planning (519) 836-6050
- Mark Johnson (ARC) (403) 438-7560
- Rich Courtney (EMA) 299-5613 (fax) 299-5606
- Don James (IRIS) 230-4344 (fax) 276-1585
- Robin Usher (GAIA) 229-9120
- Rick Kroeker (Golder) 259-3413
- Miles Scott Brown (Komex) 247-0200
- Roy Carruthers (UMA) 283-4961
- Bruce Smedley (AGRA)248-4331
- Al Wakelin (Chem-Security) 250-0555
- Jeff Dechka (Bercha Group) 270-2221

Software Houses

- Michael Simmons (Interra) (613)226-5442 (fax) 5529
  Mike Landreville (Calgary)
  Dianne Thompson (Calgary)
  Bruce MacDonald (Calgary) 266-0900
  Bob Dams (613) 226-5442
- Sally Hermanson (ESRI) (604) 682-4652
- Dr. Mike Marchand (FACET)
- Kevin O'Neill (Macdonald Dettwiler) (604)278-3411 (fax) (604)278-0531
  Marcel Mercier

Actual Respondents

To Interviews:

1. ESSA	BobEveritt	Vancouver
2. NOVA	James Mitchell	Calgary
3. University of Calgary	Bill Ross	Calgary
4. Statistics Canada	Kent Hamilton	Ottawa
5. University of Alberta	Jim Beck	Edmonton
6. Alberta Forestry, Lands, & Wildlife	Jeff Bondy	Edmonton
7. Alberta Environment	Bob Stone	Edmonton
8. Alberta Forestry, Lands, & Wildlife	Lanny Coulson	Edmonton
9. Levinsohn Consulting	Al Levinsohn	Canmore
10. Alberta Energy	Frank Kloiber	Edmonton
11. University of Calgary	Michael Coulson	Calgary
12. FACET	Michael Marchand	Calgary
13. Alberta Geological Survey	Andrey Litviak	Edmonton
14. Ontario Natural Resources	Dan Marining	Guelph

To Survey:

1. Macdonald Dettwiler	Kevin O'Neill	Vancouver
2. ESRI	Sally Hermanson	Vancouver
3. Intera	Bob Dans	Ottawa
4. Environment Canada Water Resources Directorate	Geoff Howell	Guelph
5. Environmental Protection Environment Canada	Rodger Albright	Ottawa
6. EPA Region 1	Greg Charest	
7. EPA Region VII	Walt Foster	
8. EPA Region VI	Carol Langston	
9. Planning Br. Alberta Forestry,Lands & Wildlife	Della Clish	Edmonton
10. ERCB	Roger Creasy	Calgary
11. Fish and Wildlife Division of Forestry, Lands & Wildlife		Edmonton

12. Bureau of Land Management Forest Management, Roseburg, Oregon	Phil Hall	Portland
13. UMA	Blair McTavish	Calgary
14. Delta Environmental	Russ Morrison et al	Calgary
15. Ecological Services for Planning	Dave Charlton	
16. AGRA	Bruce Smedley	Calgary
17. Bercha FG & Assoc.	Jeff Dechka	Calgary
18. Concord Environmental	Rich Rowell	Calgary
19. Komex	Miles Scott Brown	Calgary
20. Case Biotechnologies	Jim Case	Calgary
21. EMA	Rich Courtney	Calgary
22. IRIS Environmental Systems	Brian Brady	Calgary
23. University of Calgary	Rongxing Li	Calgary
24. University of Regina	David Gauthier	Regina
25. University of Calgary	Rich Revel	Calgary
26. Esso Cold Lake	Alan Kennedy	Cold Lake
27. Nova	James Mitchell	Calgary
28. Weldwood	Rick Bonner	Hinton

APPENDIX D - SURVEY QUESTIONS

EIA QUESTIONS:

1. EXTENT OF INVOLVEMENT IN EIA PREPARATION.

Please indicate numerically, the priority in terms of effort, your organization places on the following sections, and on activities within each section.(One is the highest priority for each section and activity.):

___Strategic functions	___ purely theoretical
	___ research oriented
	___ stewardship of resources
	___ setting policies for development
	___ court action/dealing with compensation issues
	___ risk assessment
	___ insurance assessment process
	___ government regulatory compliance
	___ industrial group lobbyist
	___ reviewer of EIA, evaluator
	___ post-audit reviews
___External Issues	___ public consultation management
	___ facilitation of the process
	___ negotiation/mediation
___Planning & Management	___ project management
	___ conceptual development
	___ the entire process, from concept to abandonment
	___ project operations after development
	___ engineering design
	___ construction
	___ monitoring
	___ planning mitigation
	___ reclamation
___Environmental Issues	___ environmental baseline studies
	___ screening process for major impacts
	___ environmental category analysis biogeophysical assessment

___ impact identification
___ management and integration of specialties
___ identify critical potential environmental change
___ provide basis for alternatives
___ impact assessment and prediction
___ assessment of the magnitude
___ assess overall impact
___ assess alternatives
___ document preparation/statement preparation

___Technical Issues
___ ground field data gathering
___ software creation/software support
___ laboratory testing of field samples
___ emergency response planning
___ hazardous waste management planning
___ modelling/simulations

2. CONCEPTUAL STEPS TAKEN IN EIA PREPARATION.

a) Assign a priority to the conceptual steps your organization takes producing an EIA, in terms of the amount of effort and cost that goes into the completion of the steps. (Substantial cost/effort on: 1 every project, 2 most projects, 3 some projects, 4 a few projects, 5 rarely on any project, n/a never done.)

General EIA Steps.

a) conceptual project review and planning the study strategy. 1 2 3 4 5 n/a
b) baseline study and the study of natural dynamics. 1 2 3 4 5 n/a
c) describing the project actions, alternatives, and impacts. 1 2 3 4 5 n/a
d) reviewing the study, performing an EIA quality analysis. 1 2 3 4 5 n/a
e) preparing public hearings and presentations. 1 2 3 4 5 n/a
f) continual review of impacts for project life cycle (e.g. nuclear facility). 1 2 3 4 5 n/a

Detailed impact assessment steps.

g) predicting impacts. 1 2 3 4 5 n/a
h) identifying relevant human concerns. 1 2 3 4 5 n/a
i) listing valued ecosystem components or impact indicators. 1 2 3 4 5 n/a

j) assessing the magnitude of impact on ecosystem components or indicators.	1 2 3 4 5 n/a
k) recommending alternatives.	1 2 3 4 5 n/a
l) recommending inspection procedures.	1 2 3 4 5 n/a
m) planning and implementing the monitoring operations.	1 2 3 4 5 n/a
n) planning and implementing reclamation.	1 2 3 4 5 n/a

b) GENERAL EIA PROCEDURES AND METHODS. How do you rank these procedures in terms of the execution problems they have? (1 extremely difficult, 2. difficult, 3. occasional problems, 4. routine, 5. no problems, n/a not applicable.)

Screening and scope development	
a) use of a small group of core experts	1 2 3 4 5 n/a
b) interactive workshop management	1 2 3 4 5 n/a
Modelling	
c) computer systems for integration of information from specialists	1 2 3 4 5 n/a
d) model building	1 2 3 4 5 n/a
e) simulations	1 2 3 4 5 n/a
f) what-if scenario investigation	1 2 3 4 5 n/a
Research and Assessment	
g) literature search / commercially available environmental data	1 2 3 4 5 n/a
h) CD-ROM (compact disc-read only memory) database searches	1 2 3 4 5 n/a
i) pictorial map representations	1 2 3 4 5 n/a
j) matrices	1 2 3 4 5 n/a
k) checklists	1 2 3 4 5 n/a
l) networks/flow diagrams	1 2 3 4 5 n/a
m) overlays	1 2 3 4 5 n/a
Research and Planning	
n) use of regulatory agency guidelines	1 2 3 4 5 n/a
o) use of similar projects as models	1 2 3 4 5 n/a
p) use general knowledge from project types	1 2 3 4 5 n/a
q) use components from different methodologies	1 2 3 4 5 n/a
r) field data collection	1 2 3 4 5 n/a
s) ad hoc procedures	1 2 3 4 5 n/a

Communication

t) inform publics by way of:

hearing and meetings	1 2 3 4 5 n/a
presentations	1 2 3 4 5 n/a
field offices	1 2 3 4 5 n/a
informational brochures	1 2 3 4 5 n/a
demonstrations and field trips	1 2 3 4 5 n/a
press releases	1 2 3 4 5 n/a
ombudsman	1 2 3 4 5 n/a

c) For each of the five sections in the previous question, please describe the procedures with the most problems. What suggestions do you have for their improvement?

This question regarding problem areas in EIA preparation provided the most comments from the survey respondents. Many of them identified problems in more than one area. Six general areas are identified. The area that garnered the most comments was that of the complexity of the environment. A number of respondents described each EIA as unique. There was great difficulty in trying to generically describe the EIA process. Two environmental consultants and two regulatory agencies stated that each EIA prepared is unique.

Six respondents stated that model use had problems. Models were not used because of an unfamiliarity with them. This led to unrealistic expectations. Results were needed for decisions, but the model would not be fed enough, or the correct information. The problem is the lack of time and money to correctly obtain all the data required to use the model as it was theoretically designed. This led to the use of the model in a context in which it was not initially designed for. Thus there is an inability to relate the model's parameters to the physically observable data gathered. One respondent suggested that the models themselves were insufficient in terms of being able to mimic the environment. Especially in the interrelationship between ecology and economic/social concerns. This interrelationship, especially the economic side, greatly influences decision makers.

General comments regarding complexity deal with the problems of integrating and interpreting data from a large variety of disciplines and sources. Two respondents a software developer, and a regulator, mention this as a problem. There are difficulties in finding similar projects to use as models and difficulties in referencing data from existing sources. On the opposite end of the scale, too much information can also cause a problem in analysis.

The third most problematic area was the collection of data and the creation or discovery of a good data base of pertinent information. Data gathering was found to be expensive and time consuming. There is still not enough digital information available to reduce this cost. There is no baseline information to initiate an environmental analysis. One consultant stated that the digital data available was inappropriate for a specific analysis, it would not encompass the level of detail required. As well, the metadata was missing. There was not enough information to determine the quality of the digital data. Sometimes there are proprietary problems with data residing in private, non-governmental hands. The data may be in forms that are difficult to glean information from such as: old published reports, which may be hard to discover and obtain. Always there seems to be a lack of coordination amongst data bases even within the same organization. A lack of coordination makes it difficult to maintain a consistent data base. A translation between and amongst the data is required to remedy this. Continuing in the problem of a lack of data, a regulator stated that improvements are likely in the future as more data is collected digitally. The same regulator criticizes the idea that previous projects could be used as a model for current projects. This stems from the view of project uniqueness. The baseline data gathered, however, generally improves the public digital data base available for future projects.

One environmental consultant stated that the proponent in some cases does not have a focussed project. At least there is not enough site specific detail. This consultant favours the creation of an Environmental Information System for projects. The system would be used to develop areas of environmental sensitivities, and determine potential impacts. This is a time and money problem. With enough resources the development of a more complete data base can occur.

The fourth problem area is with communications. Respondents stated a need for better communications between all parties involved in an EIA. The one regulator that commented on communications suggested better communications methods for the public. Presentations seemed to be the best method for this audience. A proponent recognized the importance of graphic visuals in displaying maps of impact areas. On the somewhat opposite end of the scale, one environmental consultant criticized communications with the public. The respondent said too much time is spent in hearings. They need to be more tightly controlled to focus on the important issues.

The fifth problem area was legislation and the government's role in the process. There was criticism from two environmental consultants that environmental legislation is in a state of flux and changes often. This causes problems and delays in planning projects. The political expediency issue was recognized by an environmental consultant as dictating the course of an EIA. One regulator criticized the lack of follow-up or audit work being done to check on predictions made in an EIA.

The sixth issue was a direct complaint about the lack of time and money to complete EIA's. Five respondents identified this directly as a problem. Budget constraints hampered field data gathering, research, and data base development. A lack of money forced the use of ad hoc contractors not fully overseen by a regulatory agency to study a particular area. Cost of model development and the required data gathering were seen as detrimental to preparing a proper EIA. The lack of money was seen as a cause of the communication problem according to one environmental consultant.

3. ORGANIZATIONAL PHILOSOPHY IN CONDUCTING EIA'S

a) What are the predominant, initial terms of reference that guide the strategy and planning of every EIA? Please rank the following. (1 being the highest.)

___Priority is placed on economics and contract terms with the proponent.
_1_Priority is placed on ensuring the basic regulations and licensing requirements are met.
_2_Priority is placed on determining the environmental boundaries of the proposed project.
___Priority is placed on identifying project stakeholders and addressing their concerns.
___others? Please explain the priority issue.

The two dominant terms of reference that guide the strategy and planning of EIA are economics and regulations. Seven of the respondents felt this way. One regulator thought that too much emphasis is placed on economics and not enough on the environment. In addition one environmental consultant stated that eventually all terms are distilled to their economic components before a decision is made as to their value. An interesting comment was made by two environmental consultants in that the terms of reference as stated in the question were seen as constraints not priorities. Priority is placed on understanding the magnitude and possible consequences of the proposed action and management resources requested/allocated to do an adequate job (science, people, time, $). Two respondents stated that all four terms of reference, stakeholder's concerns, economics, regulations, environment, were equally important. One regulator thought that there was too much emphasis placed on regulations.

b) What are the internal benefits to the EIA in the project's planning stage?

This question delved into the internal benefits of the EIA process. Answers were classified according to four categories. First, the prediction capability that was made available through the use of an EIA was seen as a definite advantage. It allowed such things as the preparation of mitigation plans, identification of potential problem areas, and better cost control, both in the EIA and in the project itself. Better planning always reduces costs in the long run. The ability to pull together diverse data, and the synergy that results, was seen as an advantage. The prediction benefit was manifest in the participation and buy-in to the project by a wider range of stakeholders. Then less time needs to be spent on public communication exercises.

The second benefit was reduced costs. Reduced costs in replacing incomplete plans, reduced costs in identifying impacts and planning for them before they occur.

The third benefit was the avoidance of conflict. A regulator stated that the opportunity to share information with experts, and the occasion to buy-in to the project by potential detractors, was beneficial in reducing costs, and improving environmental acceptability. An environmental consultant stated that "Scoping of issues can lead to formulations of alternatives early on and avoid conflict at a later date when positions are firmly entrenched".

The final benefit was seen as the preparation of better policies. Gathered data in EIA's can later be used to guide policy decisions and aid in monitoring.

c) What are the external benefits to the EIA in the project's planning stage?

Three external benefits were seen by respondents. First the generation of alternatives was seen as a better decision making tool.

Second was the response given by a regulator that better care was given to the environment.

The most commonly stated external benefit was the reassurance of society in general as to the care being given to the environment. The comments stated that there was a benefit in having experts pour over various plans in order to ensure proper planning took place. The ability to identify all relevant concerns was seen as an advantage by proponents, regulators, and consultants. This reassurance also meant that the results of studies were communicated to the experts and the public at large, another benefit whose advantage would be the mitigation of conflict in later project stages.

The proactive nature of the process was seen as a good idea by one environmental consultant.

4. a) What does the EIA process cost as a % of total project costs?

Generally this question resulted in a cost range of between 1 - 5 % of total project costs. Two consultants stated that the cost could go over 5%. One regulator made the comment that the cost was irrelevant to her organization. Only two respondents could not state a cost estimate.

b) How long does it take to perform an EIA?

Six respondents stated the time taken for an EIA is directly proportional to the project scope. The majority stated that the time taken varies anywhere from 1,2,3 or more months.

A smaller number stated that in their experience the time taken for their EIA's was 6 months and more.

Only one regulator stated that the time limit set by the regulator dictated the EIA's duration.

Responses indicated that the time taken for an EIA varied tremendously and was completely project dependent.

c) What are the rules of thumb in making schedule estimations?

There were a number of different responses for this question. Three respondents stated there could be no rules of thumb.

Two suggested that the schedule is somehow related to the project size, but they did not elaborate further.

Four respondents stated that the project complexity affected the schedule.

The presence of money would extend the schedule, thus suggesting two things. First that there never is enough time and money to complete a proper EIA. Or second that the EIA would never finish if there was an infinite money supply.

Two respondents stated that the environment played a role in the schedule by forcing certain activities to occur at certain times. For instance scheduling field data gathering by seasons.

Regulations affected two respondents in that the agencies approving their projects had set schedules they had to abide by.

One regulator could only offer Murphy's law as a rule of thumb, that rule being to be prepared for the unexpected.

One consultant offered the observation that the Environmental game is such that the field measurement is done with a micrometer, planning done with the accuracy of a chalk line, and construction is done with the delicacy of an axe. In other words crude results should be expected from elegant plans.

5. Does the EIA improve the way the projects are managed?

Ten respondents stated that EIA did improve project management. Only one stated it did not. Five were indifferent, stating that it sometimes helped in managing projects.

a) Does it provide the project decision support that it is intended to provide?

As to providing project decision support, eight respondents stated that this occurred. Some of them qualified this answer by suggesting that the information provided through the EIA might not be listened to and used by the decision makers in reaching their conclusions. Four respondents stated that the decision support was not present another four stated that it was sometimes present. Some of thè reasons why, were that a large project's EIA was not designed to support decisions, either because of political pressure for a social benefit such as jobs, or too often EIA's were structured to support decision already made.

b) What types of decisions does it support? Please rank the most important decisions EIA supports. (1 the most important, 2. very important, 3. rarely important, 4. routine, 5. never important.)

Strategic Issues

___site selection,
___facilitate project financial arrangements,
___government regulatory issue resolution,
___managing the public interface,
___dissemination of public information to the media,
___sustainable development tradeoffs,
___others? Please explain the important strategic issues.

There were some additions to this section. First all of the strategic issues listed were seen as important or at least their priority varied with the project. Second job creation especially in the native sector was seen as a strategic issue.

Engineering Design Criteria

___human transportation routes
___product transportation routes
___mitigating construction impact, access for equipment for all corridors and facilities,
___setting abandonment and reclamation plans.
___others? Please explain the important engineering issues.

Five respondents identified the use of alternative process technology, construction techniques, improved siting, and reclamation plans as additions to the list.

Operating Issues

___altering operating parameters,
___process selection
___waste stream
___input stream
___emergency response planning,
___others? Please explain the important operating issues.

One environmental consultant identified resource conservation as an important operating issues to be accounted for in decision making.

c) What effect does EIA have on the project approval process?
_1_Does it streamline the process?
_2_Does it hinder the process?
_3_Does it have a neutral effect on the process?

Why does it have this/these effect(s) on the project approval process?

Ten respondents stated that the approval process was hindered by the EIA. Reasons for this varied. Two consultants stated that approval would occur more quickly if the EIA process were eliminated. A U.S regulator stated that the process is not created to streamline project approval, but rather to help the process of analysis, creating options, and garnering public opinion. Another consultant stated that the process is not streamlined, it needs to be less bureaucratic. A regulator tends to agree with this view stating that an EIA can modify the approval process itself, it can lengthen the project approval stage, and procurement stage. A different consultant stated that the process, by allowing different intervener groups to voice opinions, prolongs the process. Two regulators state that the process might hinder approval. One reason is because of the need for research. But this research allows consideration of a great deal of public factors and regulations which are beneficially put in place. One consultant states that the process if followed as suggested in the regulations and performed by competent individuals, will result in a faster approval than a hastily completed EIA.

Four respondents stated the approval process was streamlined. One consultant explained the following: "It (the EIA) describes the site to the (regulatory) board, outlines the proposed development and location of development. It describes perceived impacts based on what will be removed or altered and ranks them accordingly. Residual impacts, cumulative impacts, and remediation are also highlighted for the board. Assessment is based on quantifiable data as much as possible and supported by research studies. For the board an EIA takes the guesswork out of evaluating an impact or impacts on a site due to project developments."
A U.S regulator stated that "The EIA is primarily used by our agency as a planning tool and a decision making document. By having all the information we feel comfortable in making an informed decision on proposals."
Another consultant and regulator essentially say that a well communicated and effective EIA in which all issues have been predicted and discussed in advance will be approved much more easily than one that is missing these elements.

Six respondents state that the process can have either effect. The extra time taken to complete the study was seen as a hindrance. The opportunity to analyze, garner opinion, and create alternatives was seen as the benefit. One consultant adds that the process depends somewhat upon the skills and attitudes of the people involved.

Two respondents were indifferent to the processes effect. In one case the consultant stated that the approval process rarely uses the EIA information, economics and social needs are the predominant forces. Another respondent stated that since it is required by regulators, it does not matter if it hinders or streamlines the approval process, the EIA must be completed.

GIS QUESTIONS

6. Which commercially available GIS products are you aware of? If familiar with the product please rank its capabilities. (1. Best, 2. Very Good, 3. Satisfactory, 4. Occasionally useful/capable, 5. Rarely useful/capable, n/a not applicable, unaware of product)

Arc/Info	1 2 3 4 5 n/a
Intergraph	1 2 3 4 5 n/a
Pamap	1 2 3 4 5 n/a
Nucor	1 2 3 4 5 n/a
Spans	1 2 3 4 5 n/a
Idrisi	1 2 3 4 5 n/a
Geomap	1 2 3 4 5 n/a

others? Please list and rank.

7. Is a GIS used in your organization?

Individually rank the uses, in order of priority. If you do not use a GIS, please rank how you would see it as potentially being used. (1. Best use, 2. Very good use, 3. Satisfactory/Routine use, 4. Occasional use, 5. Rarely useful, n/a not useful)

Modelling and Data Management	
a) computer systems for integration of information from specialists	1 2 3 4 5 n/a
b) model building	1 2 3 4 5 n/a
c) simulations	1 2 3 4 5 n/a
d) what-if scenario investigation	1 2 3 4 5 n/a
Research and Assessment	
e) literature search / commercially available environmental data	1 2 3 4 5 n/a
f) CD-ROM (compact disc-read only memory) database searches	1 2 3 4 5 n/a
g) pictorial map representations	1 2 3 4 5 n/a
h) matrices	1 2 3 4 5 n/a
i) checklists	1 2 3 4 5 n/a
j) networks	1 2 3 4 5 n/a
k) overlays	1 2 3 4 5 n/a
l) flow diagrams	1 2 3 4 5 n/a

Research and Planning

m) use of regulatory agency guidelines	1 2 3 4 5 n/a
n) use of similar projects as models	1 2 3 4 5 n/a
o) use general knowledge from project types	1 2 3 4 5 n/a
p) use components from different methodologies	1 2 3 4 5 n/a
q) field data collection	1 2 3 4 5 n/a
r) ad hoc procedures	1 2 3 4 5 n/a

Communications

s) inform publics by way of:

interactive workshop tool	1 2 3 4 5 n/a
presentations	1 2 3 4 5 n/a
workshops and task forces	1 2 3 4 5 n/a
demonstrations and field trips	1 2 3 4 5 n/a
others? Please list and rank	

8. Where do you see GIS fitting into the scheme of EIA preparation most effectively? Rank the following as being candidates for using a GIS.(1. Best use, 2. Very good use, 3. Satisfactory/Routine use, 4. Occasional use, 5. Rarely useful, n/a not useful)

General EIA Steps

a) conceptual project review and planning the study strategy.	1 2 3 4 5 n/a
b) baseline study and the study of natural dynamics	1 2 3 4 5 n/a
c) describing the project actions and alternatives	1 2 3 4 5 n/a
d) reviewing the study, performing an EIA quality analysis.	1 2 3 4 5 n/a
e) preparing public hearings and presentations.	1 2 3 4 5 n/a
f) continual review of impacts for project life cycle(e.g. nuclear facility).	1 2 3 4 5 n/a

Detailed Impact Assessment Steps

g) predicting impacts	1 2 3 4 5 n/a
h) identifying relevant human concerns	1 2 3 4 5 n/a
i) listing valued ecosystem components or impact indicators.	1 2 3 4 5 n/a
j) assessing the magnitude of impact on ecosystem components or indicators.	1 2 3 4 5 n/a
k) recommending alternatives.	1 2 3 4 5 n/a

l) recommending inspection procedures. 1 2 3 4 5 n/a
m) planning and implementing the monitoring operations. 1 2 3 4 5 n/a
n) planning and implementing reclamation. 1 2 3 4 5 n/a

9. Improving The Efficiency And Effectiveness Of EIA Preparation. If you were building a decision support system, for the improvement of the EIA process, what parts of the EIA process should be streamlined with the use of GIS? Rank the following in order of importance.(1. Best use, 2. Very good use, 3. Satisfactory/Routine use, 4. Occasional use, 5. Rarely useful, n/a not useful)

Strategic Planning
a) conceptual project review and planning the study strategy. 1 2 3 4 5 n/a
b) baseline study and the study of natural dynamics 1 2 3 4 5 n/a
c) describing the project actions and alternatives 1 2 3 4 5 n/a
d) reviewing the study, performing an EIA quality analysis. 1 2 3 4 5 n/a
e) presenting public hearings and presentations. 1 2 3 4 5 n/a
f) continual review of impacts for project life cycle (e.g. nuclear facility). 1 2 3 4 5 n/a

Impact Assessment
g) predicting impacts 1 2 3 4 5 n/a
h) identifying relevant human concerns 1 2 3 4 5 n/a
i) listing valued ecosystem components or impact indicators. 1 2 3 4 5 n/a
j) assessing the magnitude of impact on ecosystem components or indicators. 1 2 3 4 5 n/a
k) assessing alternatives. 1 2 3 4 5 n/a
l) assessing inspection procedures. 1 2 3 4 5 n/a
m) planning and implementing the monitoring operations. 1 2 3 4 5 n/a
n) planning and implementing reclamation. 1 2 3 4 5 n/a

Research and Planning
o) use of regulatory agency guidelines 1 2 3 4 5 n/a
p) use of similar projects as models 1 2 3 4 5 n/a
q) use general knowledge from project types 1 2 3 4 5 n/a
r) use components from different methodologies 1 2 3 4 5 n/a
s) field data collection 1 2 3 4 5 n/a
t) ad hoc procedures 1 2 3 4 5 n/a

Communications

u) inform publics by way of: presentations 1 2 3 4 5 n/a

demonstrations and field trips 1 2 3 4 5 n/a

workshops and task forces 1 2 3 4 5 n/a

interactive workshop management 1 2 3 4 5 n/a

v) others? Please list and rank.

10. Given that GIS can be used to enhance the EIA process, there may be human resource and institutional impediments to the implementation of GIS for an EIA process.

a) What human resource skills are required to implement GIS for an EIA process?

The respondents felt that there was a predominant need to have computer science and GIS skills in order to use GIS to help prepare EIA's. EIA experts must be experienced in querying a GIS and they must be cognizant of the typical errors that can result. Programming skills were seen as useful, potentially to develop model algorithms. Not only are software specialists required but also those knowledgeable in the hardware. On the GIS application side they must be familiar with the terminology, (i.e. polygon, image, overlay, etc.) and the issues in geomatics. One of the respondents specifically mentioned the need for management to become familiar with the concepts mentioned in this paragraph. The ability to think spatially is a benefit in using a GIS. The development of personnel that are competent in this area could take anywhere from 2-4 years. And these specialists need to be the scientists doing the scientific studies in an EIA.

The second important requirement is for the scientists to be properly trained in the environmental or resource sciences. They need a solid background in the field of study (i.e. biology, ecology, anthropology, etc.). Even a geographic knowledge and familiarity with a particular area in the world is of benefit. This would have the benefit of being able to identify key indicators quickly, focussing the EIA and reducing the cost of the EIA preparation.

The final area is in communications and project management. This is important to ensure the decision making is based on the correct criteria as communicated by the stakeholders. Presentation skills are seen as important, along with the ability to communicate interdisciplinary and work interdisciplinary.

b) What do you think the institutional impediments are?

There are six areas of impediments. Nine of the respondents mentioned that there was a general lack of understanding of the GIS capabilities, both by the lay people and the upper management people making decisions. Management is lower down the learning curve in understanding the new technology. Often the GIS is not used because of a general lack of computer knowledge.

This is further complicated by the lack of any time to learn the use of a new tool. For the users that know computers to some extent, the issues of concern are data base quality, accessibility, and timeliness.

The data that are in the GIS must conform to standards that are acceptable to the organization using the data. The processes used in the data collection, and the criteria used in gleaning information from the data, are also of concern to the respondents. In some cases the data that has been gathered by an organization is in a format unsuitable for use in a GIS. Fortunately one respondent states that this situation is changing as more digital data is being prepared. But currently an entire EIA might be complete before a suitable set of data is gathered for input into a GIS.

In some cases there is a lack of acknowledgement that EIA professionals with GIS skills are required and preferable. The GIS functions are carried out by separate data processing professionals.

The second most prevalent response was that of a concern about the money required for GIS. The benefits were difficult to quantify. The cost of data collection is prohibitive in some cases. The GIS implementations are usually underfunded. 80% of the time and money is spent on data collection and 20% on analysis.

The third most popular response was the fear of the technology. Resistance builds up due to the present systems, manual or automated, that are in place. The people in place are not willing to try new things. As well the regulators have to be educated as to the benefit of a new approach of GIS.

Only three respondents mentioned the problem of departmental friction. One consultant mentioned the problem of trying to integrate different data base systems across departmental lines. A federal regulator suggested that a team approach would help integrate effort across organizational lines.

This respondent went further and specified that the team approach would be effective only with upper management support.

c) In your opinion what are the essential skill sets that the next generation involved in GIS and EIA will need? Please rank them in order of importance, 1 being the highest ranking.

___ Data management,
_2_ Geo-informatics, GIS,
___ Project Management,
_1_ Environmental planning,
___ Communication skills,
___ Others. Please explain.

This question, in addition to the ranking, had a mixture of comments. Eight different response comments were made. The synergy of the team was seen as a way of ensuring that the proper skill sets were in place in order to prepare EIA's. This meant that no one person could provide all the necessary expertise, instead a team should be used to ensure all the expertise is available. The building of this team would have a synergistic effect, and improve the result of the EIA process. The synergy would only happen if all the required skills are in place on the team. It would be cost beneficial to have one 'superman' with a combination of all the skills, but for larger projects this is just not possible.

Three respondents stated that the most important skill is that of understanding computers and the intricacies of data transfer. Specifically transfer between different GIS systems. A respondent stated that the modelling, programming, and remote sensing skills are required of the professionals working on an EIA. There is a need for EIA professionals, biologists for instance, to become proficient in the use of these new GIS tools. At the same time GIS must be understood to be only a tool, not something that can replace the experts with information as to how to prepare and conduct an EIA.

The people involved in preparing an EIA must be aware of the intricacies involved in trying to model the environment. The computer models that they create must be constructed according to ecological principles, or according to good scientific research. For this to occur, they must be trained in the environmental sciences. They must be able to perform or plan such activities as:

field data gathering, wildlife assessment, planning mitigative measures, risk assessment, and evaluations.

One respondent stressed the need for team management skills. The interactive nature of GIS requires a team approach to application development. This means that people with advanced team building and team management skills will be essential.

Two conflicting views were expressed by two respondents. A software developer stated that as better tools were developed, the need for special GIS experts will diminish. Conversely, a regulator thought that the better tools would preclude the need for environmental experts.

d) On the basis of the answers to c), do present EIA professionals have the skill sets identified?

Most respondents thought the present professional either did not have the skills required, or partially had the proper skill sets. Only three respondents, including a University thought that the present professionals had the proper skills. The partial respondents indicated that there was a lack of communications skills, GIS knowledge. A common observation was that the scientists involved in preparing an EIA have the scientific disciplinary skills but not the modelling and GIS skills.

e) Which of the skills do you expect to be taught as core skills (say at University), and which do you expect to be gained through "in-career" professional development.

There were some additional comments as to the preference of the respondents to what they thought were appropriate core courses. Six of the respondents thought that all of the skills listed should be core and taught in University. The analytical abilities of how to attack and solve problems are important. For management the communications skills were especially important.