

THE APPLICATION OF COMPUTER TECHNOLOGY TO
ENVIRONMENTAL IMPACT ASSESSMENT (EIA)

by

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ABSTRACT

Computer technology, like Environmental Impact Assessment (EIA) has undergone rapid and extensive development during the last decade. Coupled with recent initiatives toward environmentally sustainable economic development, an opportunity is provided to shift our perspectives and practices about data and information toward the improvement of the use of computer technology in EIA.

Today, a number of computerized systems are available to be applied to the activities associated with environmental assessment. While some technologies are well developed and others are evolving, the challenge is to integrate all of the various technologies for application to EIA.

This report discusses the major components of environmental impact assessment; how EIA is practised in Canada; and the various categories of current computer systems such as, Data Base Management Systems (DBMS); Computer Aided Instruction (CAI); Geographic Information Systems (GIS); Decision Support Systems (DSS); Expert Systems (ES) and Computer Modelling that could be applied to the EIA process. Following the summary of computer systems, a brief description of a number of applications to EIA are provided.

1.0 INTRODUCTION

The advancements of science and technology, the development of human cultures, and the intensity of human activities have all contributed to the high standard of living many of us enjoy today. However, these same elements, coupled with our uncaring attitude toward the environmental consequences of our actions, have produced a complex array of environmental impacts that threaten our way of life and survival. Evidence concerning global warming, ozone depletion, species and habitat reduction and elimination, forest destruction, the spread of deserts, soil degradation, acidification of lakes and streams, and surface and groundwater pollution exists in abundance in the literature. The environmental problems we face today are due to unsustainable economic development and growth in industrialized countries. As third-world countries accelerate their economic development in order to raise their standards of living to those of developed countries, these environmental problems will worsen.

Systematic attempts to mitigate environmental impacts are only about two decades old. In this brief period, our understanding of the strategies required to control environmental impacts has undergone a fundamental change. During the last 20 years, our approach to dealing with these environmental impacts has been one of react-and-cure. This approach concentrated on local environmental effects and damage by imposing emission standards, and by incorporating environmental factors into project design. Today, the growing evidence that environmental problems are global in scope, and that they could limit economic development, has led to the urgent need to reassess the react-and-cure approach and to adopt an anticipate-and-prevent approach, one that will ensure that environmental considerations are integrated into decision-making at the early planning stages of proposed development initiatives. Environmental impact assessment (EIA), a planning tool that had its beginning in the late 1960s, has evolved as one of the most effective mechanisms available to help decision-makers deal effectively with the environmental consequences of their decisions.

Like EIA, computer technology has undergone rapid and extensive development during the last decade. The technology has evolved in its application to financial management, and the management of natural resources and environmental assessment. In addition, a micro-computer revolution is underway. Complex systems that were previously only available on large mainframe computers are now available in desk-top computers. We now have a powerful technology that we can use to help practitioners and managers improve the effectiveness and efficiency of EIA.

This report discusses the major components of EIA; how EIA is practised in Canada, and the various categories of current computer systems that could be applied to the process. The report provides a brief description of a number of applications by a number of

Canadian firms that will be demonstrated at GLOBE'90.

2.0 ENVIRONMENTAL IMPACT ASSESSMENT

EIA is one of the most effective approaches to anticipating and preventing environmental damage. It attempts to identify, predict, and assess the likely consequences of proposed development activities, be they biophysical, socio-economic, cultural, or health-related. The ultimate objective of EIA is to promote the integration of environmental considerations into all social and economic development decisions. EIA provides one of the essential tools that can and should be used to achieve the goals of environmentally sustainable economic development, a concept that has been entrenched universally following the publication by the United Nations General Assembly of the Brundtland Commission's 1987 report, "Our Common Future". EIA should be seen as a test, as fundamental as that of economic feasibility, when considering economic development initiatives at the policy, program, or project level.

EIA was first incorporated as a regulatory procedure in the United States under the 1969 National Environmental Policy Act (NEPA). NEPA required that all actions significantly affecting the quality of the human environment would be subject to an EIA. Since NEPA, other countries have adopted similar provisions which make EIA a prerequisite for integrating environmental considerations into economic decisions, as well as for the approval of development proposals.

Most EIA processes attempt to identify, analyze, and evaluate in a comprehensive and systematic way the likely consequences of proposed development activities, through an open, participatory, and consistent process. Such an interactive system can be thought of as a set of elements connected together to form a whole. The properties of the whole emerge from the interactions of the elements. The elements of EIA are the following:

APPRAISING BASELINE INFORMATION: It is necessary to collect and collate data about the state of the environment and to analyze the quality of the temporal and spatial variations in the data. The data can then be presented as information. While much information can be obtained through existing data bases and individuals knowledgeable about the environment, monitoring studies are required to collect data to fill in information gaps. If baseline data needs to be collected, monitoring must be carried out early in the planning stages.

IDENTIFYING ENVIRONMENTAL HAZARDS: It is important to identify the environmental hazards associated with a proposal and to predict the effects they may have on humans and the environment.

ASSESSING ENVIRONMENTAL IMPACTS: The central component of EIA is prediction of the impacts of a proposal on humans and their biophysical and social environments. In addition, knowledge about the methods that can be applied to mitigate the impacts of a development must be obtained, and if this is not possible, measures of compensation must be identified. Adverse environmental hazards can be mitigated in the planning and operational stages. Compensation procedures can help in the re-creation of habitats where mitigation measures are not expected to be effective. The remaining task is then to assess the significance of the residual impacts, and to determine the risks associated with them.

PUBLIC INVOLVEMENT: An important and essential component of EIA is public involvement. Involvement includes identifying stakeholder(notifying stakeholder about the proposal; communicating the nature of the proposal, including associated risks; listening to the public's concern about the proposal and involving the stakeholder (s) in the design of the proposal. Effective public participation is a vital link to the long-term validity of the resulting mitigation and compensation responses.

FOLLOW-UP: When all of the information has been identified, analyzed, and evaluated, and a decision rendered, it is important to outline the mitigation and compensation commitments that should be implemented. As well, monitoring plans that will be employed for detecting changes and problems and for improving upon the methods, techniques, and approaches used in prediction, mitigation, and compensation should be developed.

3.0 THE FEDERAL ENVIRONMENTAL ASSESSMENT AND REVIEW PROCESS (EARP)

In Canada, EIA evolved from a 1973 federal cabinet decision to establish the Environmental Assessment and Review Process (EARP). The process was established in 1984 as an Order-in-Council. More recently, a number of events have resulted in a move towards establishing an Environmental Assessment Act for Canada. EARP can be seen as two distinctive but inextricably linked

processes. One is the Environmental Impact Assessment Process and the other the Environmental Follow-Up Process. The processes are described below.

3.1 Environmental Impact Assessment (EIA) Process

The environmental impact assessment process encompasses the activities that must be taken to assess the potential impacts of a given project on the physical, biological, social, cultural and economic environments; to identify the mitigation and compensation which would reduce or eliminate the impacts; to undertake other follow-up activities that may be required (e.g., monitoring, research, auditing) and to take a decision on project acceptability. In the EARP, this process can be separated into two phases. First, there is the initial assessment which provides screening and the initial environmental evaluation. The initial assessment phase involves a systematic, documented assessment of environmental implications of a proposal, including the significance of adverse environmental consequences which may impact on the project. Screening determines the need to mitigate environmental impacts, and indicates whether further investigation is required. An exclusion list assists in the identification of proposals that would not be expected to produce any adverse environmental effects, and should thus be excluded from any more detailed examination under the EARP.

If, during the Initial Assessment Phase, it is found that there is a need for further investigation of the nature, extent, and significance of the impacts and the efficacy of known mitigation and or compensation measures, than an Initial Environmental Evaluation (IEE) is conducted. If the initial environmental evaluation determines that the effects are insignificant or they can be adequately mitigated or compensated, then the proposal can be allowed to proceed (Figure 1).

The second phase is the Public Review. This phase is undertaken when a proposal's adverse environmental and directly related social effects are significant, or if public concern is such that a public review is desirable. The proposal is subject to a detailed examination by an independent panel, with opportunity for public involvement (Figure 2).

3.2 Environmental Follow-Up Process

The environmental follow-up process encompasses post-assessment activities including monitoring. Follow-up activities are undertaken to ensure the implementation of the proposal in accordance with the terms imposed by the environmental impact assessment process, and to learn from the particular activity being studied in order to provide for modifications or changes where

Figure 1

Initial Assessment

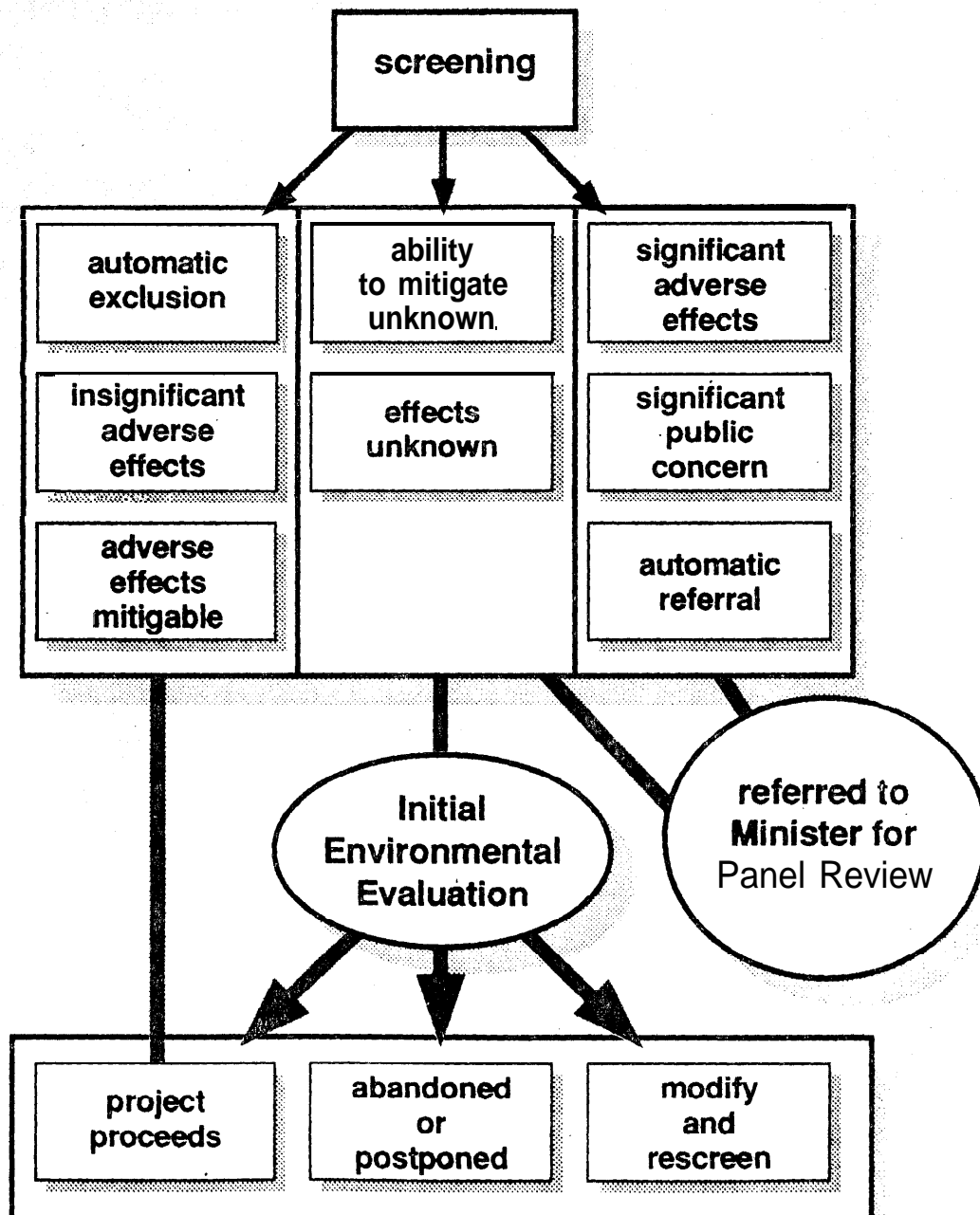
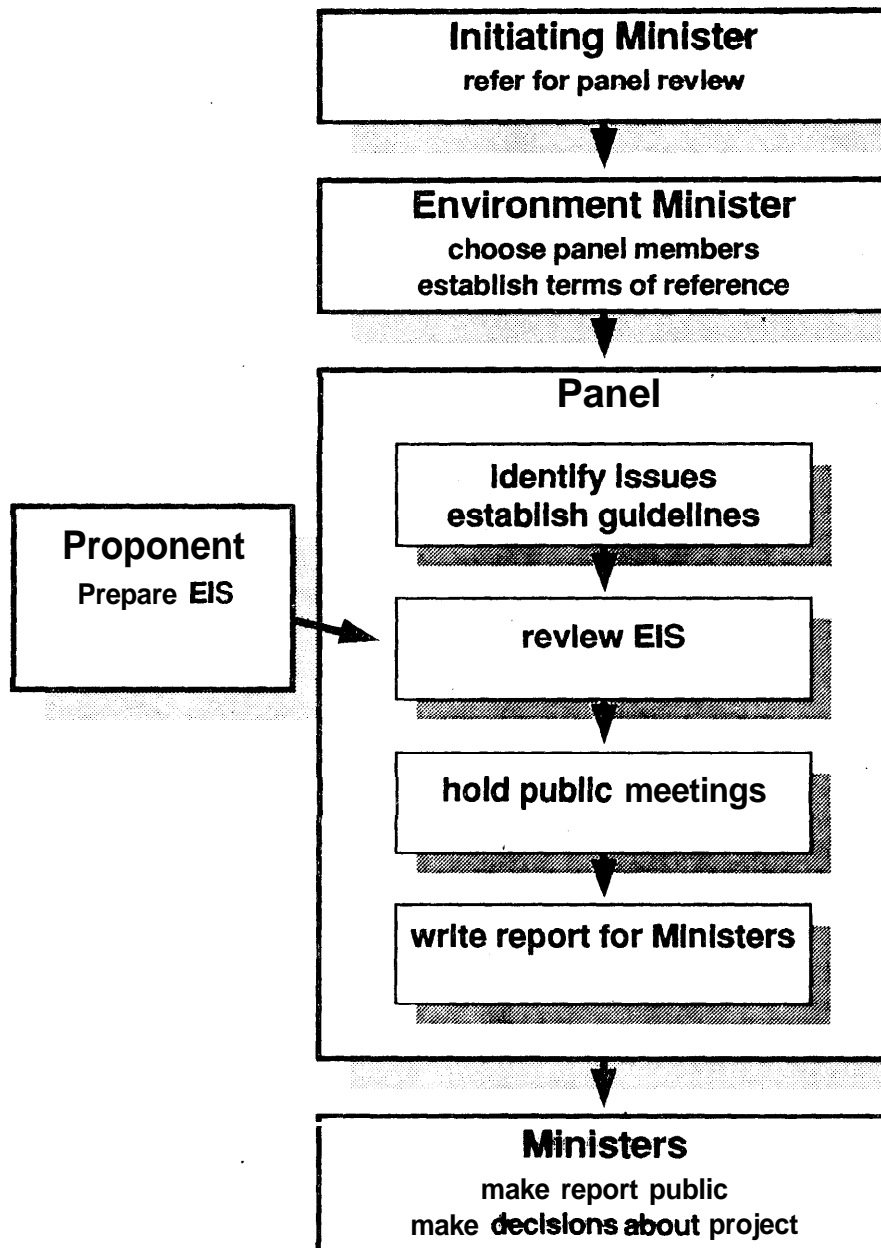


Figure 2

Panel Review



required.

Key to the success of this phase is the development of Environmental Management Plans and the involvement of regulatory agencies and the public in the development and implementation of the plan. These plans are outlined in documents which articulate how the commitments made during the EIA Phase will be implemented to manage the impacts of the project throughout its lifecycle. These plans include descriptions of precisely how mitigation, and monitoring will be implemented.

The various components of the environmental management plans are as follows:

- Mitigation Plans aim to describe in detail the methods and techniques to be applied to the elimination or reduction of the negative effects and risks of an initiative, and the regulation and control of those effects and risks where they occur.
- Compensation Plans describe those techniques that are aimed at redressing or offsetting the unavoidable negative effects of an initiative which can not be adequately mitigated.
- Contingency Plans identify how the detection and timely response to potential divergencies and unanticipated problems will be addressed.
- Community Involvement Plans provide the means by which effective two-way communication and problem-solving can be implemented on an on-going basis.
- Monitoring Plans identify data collection and evaluation for the purposes of determining the changes which may have occurred as a result of the project. The monitoring plan should cover several types of measurement activities, with differing purposes. The two main types of monitoring are:

(1) Effects monitoring: This involves the measurement of environmental variables during project construction and operation to help in the determination of changes that may have occurred as a result of the project.

(2) Compliance monitoring: This takes the form of periodic sampling and/or continuous measurement of the levels of waste discharge, noise, or similar emission to ensure that

conditions and standards are met.

- Audit Plans cover the evaluation of adherence to terms and conditions or established procedures.

4.0 COMPUTER TECHNOLOGY AND EIA

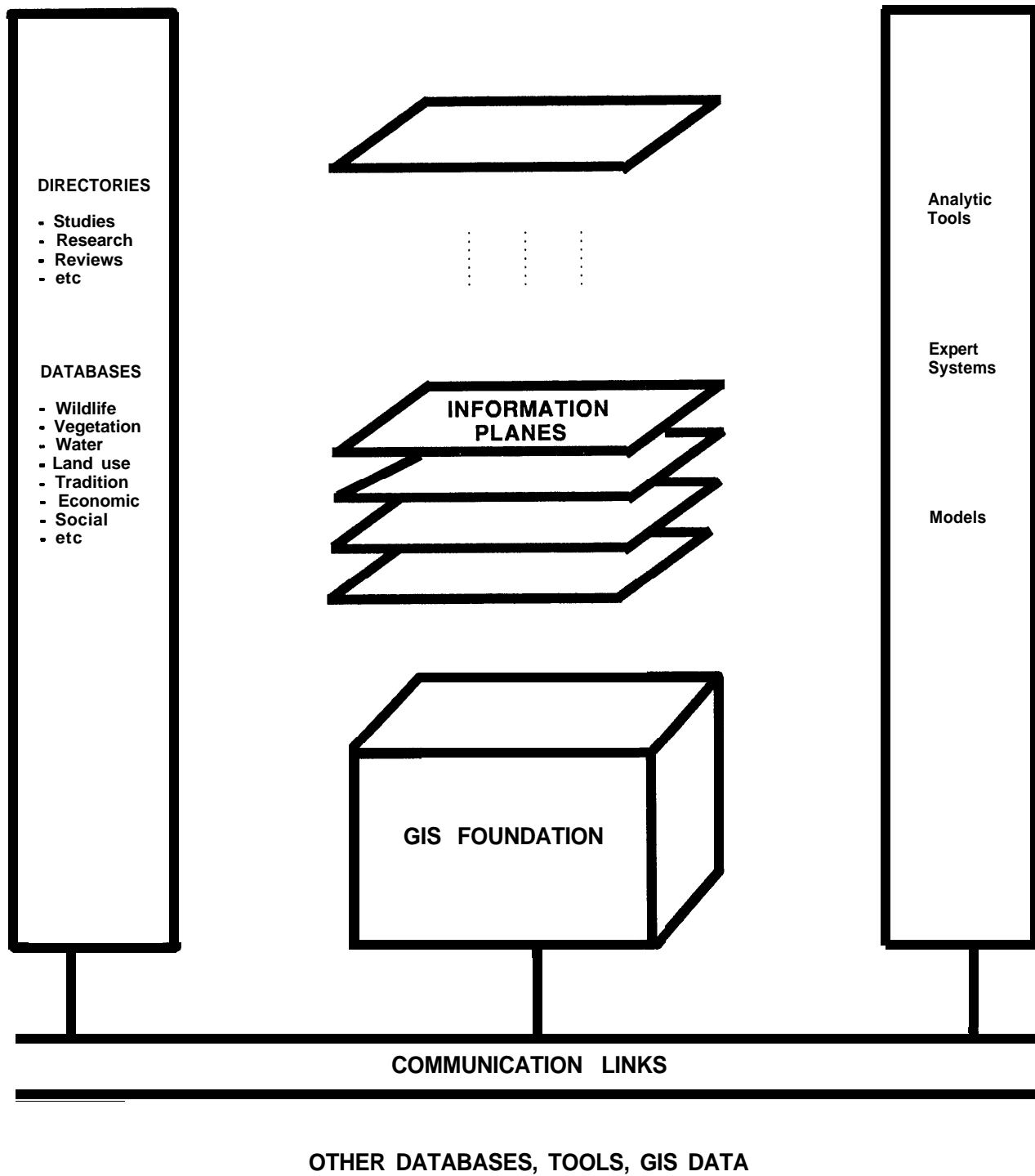
Advancements in computer hardware and software provide an opportunity to greatly improve the use and effectiveness of EIA in decision-making.

Today, a number of computerized systems are available to be applied to the activities associated with environmental assessment. Computer technology can provide valuable assistance to EIA researchers, managers, and practitioners. Because EIA is an integration of various disciplines, the application of computers to EIA will need to integrate all the various technologies available. Some are well developed, while others are still evolving. The challenge is to integrate all of these for application to EIA (see Figure 3). The computer-based systems that can be applied to EIA are discussed below:

4.1 Data Base Management Systems (DBMS)

These systems manage large amounts of similar data such as physical, biological, and chemical data that is collected and collated for EIAs. Systems may be relational, i.e., the system components may be linked by the user so that when one file is updated, simultaneous updating of other relevant files will occur. While the initial set-up of a DBMS may be relatively complex and beyond the scope of the casual user, the actual use of such a system can be simplified by the use of built-in commands which allow a user to call up a database directly and store or retrieve data as required. DBMS allow the user to define criteria, such as date, subject, or range for any factors or combinations of factors. Reports presenting statistical summaries may be generated on the selected data. DBMS that can handle non-numeric data, such as long text fields are also available. An example is a bibliographic system which can locate environmental information in technical or scientific reports. Such a system allows the user to retrieve EIA-related information by author or subject keywords.

Figure 3
AN EIS TECHNOLOGY MODEL



4.2 Computer-Aided Instruction (CAI)

With computer-aided instruction systems, users can be presented with a hypothetical situation and then offered choices for further action (e.g., gather more data on the impact, make a decision). Choices are then evaluated by the program. Graphics can be used where appropriate as an aid to instruction. The size of any such training package is limited only by the hardware used, as programs may be linked to each other. As well, varying levels of challenge can be built into the package to accommodate users at various levels of expertise. This system, like a decision support system, can help lead to development of a standardized approach in EIA.

4.3 Geographic Information Systems (GIS)

GISs have evolved from computer mapping packages, which place primary emphasis on the display of data, to systems with a capacity for sophisticated analysis and management of geographic data, including the following functions:

- The **storage** of geographic data in which many types of different information are coded and stored in graphic (map) form;
- The **analysis** of geographic data, for instance topological overlays for extracting or creating new data that meets some required conditions; and
- The visual **display and production** of geographic data maps on colour monitor, printer or plotter.

GIS can be adapted to become a decision support system, or an expert system, or can provide significant modelling capabilities. GIS is an important integrator of data and can analyse data in a manner that has often not been done before.

4.4 Decision Support Systems (DSS)

This general term may be used to describe any system that allows efficient use of methods of analysis and information to aid in the development of decisions. Such a system may be a hybrid composed, for example, of a simulation model (e.g., for the effect dam construction) and a rule-based system that develops a decision or refines the criteria for reaching a decision, based on

the users' answers to a series of questions. The system represents a cumulative pool of knowledge to which all users have access. A DSS can help a community to analyse the potential impacts of a proponent's plans, and to demonstrate modification of aspects of the plan.

4.5 Expert Systems (ES)

An expert system is a computer tool that provides the judgement of experts to a large number of people in a user-friendly fashion. Typically, the knowledge is in the form of facts (information specific to the problem at hand), and rules (reasoning methods for using the facts) used to arrive at conclusions about the problem. By combining these two elements, the expert system uses both its reasoning power and the knowledge possessed by the user to make reasonable and comprehensive decisions.

Expert systems can be used in two ways: experts use the system to enhance and corroborate their own ability to make complex decisions; less specialized individuals may require the expertise and understanding incorporated into the system in order to make better decisions. Both approaches have been used successfully in environmental assessment.

Within the community, expert systems can be used to capture the knowledge of elders and specialists and allow it to be applied to the analysis of development proposals. The ability of expert systems to explain the applied reasoning can assist in the communication of community knowledge to young people.

4.6 Computer Modelling

Modelling extracts the features involved in the problem under consideration. The model that results from the extracted features can be used to select the environmental technology best suited for the solution of specific environmental problems. Modelling allows computer simulation for impact assessment and provides the possibility of simulating the behaviour of systems as changes occur in the external variables of the environment. For example, if the computer is programmed with the tides, currents and formations of a stretch of river, and to understand how oil behaves in water, it can demonstrate the effects of an oil spill.

Computer video-imaging has also recently become available

for use in simulations. This tool is most effective when combined with Digital Terrain Modelling (DTM). DTM provides accurate simulations, however it uses line and symbol drawings so they are not very realistic. Computer video-imaging adds the realism. The system graphically manipulates images in video or photographic format. This means that a photograph of a landscape can be shown on a computer monitor and manipulated to show proposed alterations realistically based on the accurate DTM image. This allows proponents, agencies, and the public to see for themselves the potential visual impact.

5.0 EXAMPLES OF COMPUTER APPLICATIONS IN EIA

A number of applications of computer technologies have been developed by various Canadian firms. Examples of applications to EIA which have been developed and are being demonstrated during GLOBE '90 at a FEARO sponsored-display are described below:

5.1 Catherine Berris Associates Inc.

Catherine Berris Associates Inc. is a consulting firm of planners and landscape architects who provides services in research, planning, and design of land and water areas to public and private clients. Operating out of Vancouver, B.C., the firm has been involved primarily in projects in western Canada, with some international experience.

The firm is involved in a broad range of project types, from environmental and land use planning studies that include resource management, suitability analysis, and risk analysis, to recreation planning and design projects. Services range from research through analysis to the development of plans and management guidelines. Specific expertise includes consensus-based planning, public involvement programs, and conflict resolution. While only some projects may **specifically** focus on environmental impact assessment, the consideration of environmental impacts has a central role in every project undertaken.

Computer applications feature the use of geographic information systems (GIS), computer-aided drafting (CAD), database management systems (DBMS), digital terrain modelling (DTM), and computer video-imaging (CVI). These applications are used by the firm as tools to assist in all phases of the environmental impact assessment process as appropriate. The following summaries describe the ways in which the technologies have been applied to specific projects.

1. Sechelt Inlets Coastal Strategy

Sunshine Coast Regional District, British Columbia.

This project arose out of increasing demands for use of resources in a fragile coastal area, conflicts among residents and users, and concern about the area's future. With the vision of guiding the future of the area to balance development and use with a sustainable environment, resource information was documented and analyzed in a GIS and DBMS, and potential environmental impacts were assessed. The results were used for consensus-based planning with a working committee composed of the primary federal, provincial and regional agencies, industry, and two public representatives. Public open houses were held to review draft and final documents, and fieldwork and conflict resolution techniques were used as required. The result of the project is a strategy for the inlets which includes an area designation plan accompanied by guidelines and policies for implementation and monitoring. Endorsed by the agencies participating in the planning effort, it will serve to minimize the environmental impacts of future development.

2. Transport of Dangerous Goods Study GIS

Greater Vancouver Region, British Columbia.

This study involved risk analysis of existing and potential routes for transportation of dangerous goods within the lower mainland of British Columbia. A computer GIS and DBMS were used to generate road, rail, and marine networks; locations where dangerous goods are manufactured, stored, and transported; emergency response facilities; human population density and property values; and vulnerable bird, fish, and mammal populations. The computer GIS was used to analyze risk along alternative dangerous goods routes according to potential impacts on population, property, and the environment. This was produced as a tool for management and prevention of environmental impacts.

3. Surrey Environmentally Sensitive Areas

Municipality of Surrey, British Columbia.

Surrey is a large municipality close to Vancouver where the demands for development are threatening the environment. This study is being conducted with a team to assist the Municipality of Surrey in managing its resources wisely. Areas which are environmentally sensitive for physical and/or cultural reasons have been identified and entered into a GIS and the characteristics of sensitivity entered into an associated DBMS. The potential environmental impacts of development on resources have been assessed and management techniques and policies for each environmentally sensitive

area were established. The product will be a working tool to assist planners in predicting and managing environmental impacts.

4. Meager Creek Suitability Analysis

Meager Creek, British Columbia.

This project involved analysis of environmental and resource use factors to determine the most suitable areas within the Meager Creek valley for five land uses, including an international resort complex, recreational cabins, a golf course, agriculture, and industry. Topography, soils, geological hazard, solar radiation, and visual factors were analyzed using GIS as a tool for overlay analysis, and a recreation assessment of existing and proposed activities was undertaken. The purpose of the project was to site land uses and provide guidelines so that environmental impacts would be minimized.

5. Quesnel/Barkerville Corridor Simulations

Quesnel/Barkerville, British Columbia.

Digital terrain modelling and computer video-imaging were used together for visual impact assessment in an area where proposed cutting plans submitted by a forest company were opposed by the public. In conjunction with the B.C. Ministry of Forests landscape staff, simulations of the forest landscape were produced according to proposed and alternative cutting patterns. The simulations, which show the landscape as it will look over time, are being used as part of a public involvement program on forest landscape management in the area.

6. Resource Sensitivity Information System (RSIS) for Oil Spill Management

Queen Charlotte Islands, British Columbia.

As part of a multi-disciplinary team, this project involved developing a GIS and DBMS system for planning and decision-making with regard to oil spills. The project is a prototype that will identify all resources and their relative sensitivity, so that in the event of the spill, managers can make decisions about areas with the highest priority for protection and clean-up.

7. Matsqui Gravel Pit Simulations

Matsqui, British Columbia.

A DTM for a proposed gravel pit site was developed to assist

in the assessment of visual impacts. Three phases of extraction were documented, and perspectives were generated for each phase from specific viewpoints. The computer system was brought to a Council meeting and to a public meeting so that the impacts of the proposed pit from particular locations could be illustrated to decision-makers and the public.

8. Niseko West Solar Analysis

Niseko, Japan.

The site for this project is a mountain in Japan which is being planned as a ski resort. In siting lifts, runs, and mountain facilities, in order to minimize environmental impacts and best accommodate users, the client needed to identify the particularly warm spots on the mountain where snow would melt sooner, and the very cold areas which would be unsuitable for certain uses. A DTM was generated for the mountain, and in combination with GIS, perspective sketches and maps were developed simulating sun/shade patterns for 9:00 a.m., noon, and 3 p.m. on December 21, February 21 and April 21. Morning and afternoon maps were then overlaid to find the coldest and warmest areas.

9. Port Moody North Shore Simulations

District of Port Moody, British Columbia.

To assist in visual impact assessment, a proposed housing development was simulated from key viewpoints using DTM and CVI. The purpose of the project was to assist the planning staff and elected officials in their decision-making regarding development on the north shore and approvals of proposed projects.

10. Urban High-Rise Visual Impact Assessments

Vancouver, British Columbia.

Since views are so critical to the citizens and politicians of Vancouver, there is much concern about the impacts of proposed high-rise buildings. Several projects were undertaken in which CAD and CVI were used to simulate the visual impacts of proposed projects from specific locations. Concerns included blocking the views of mountain peaks from key public use areas, lack of conformity with surrounding buildings, and visual impacts on streetscapes. The simulations allowed for a clear understanding of the impacts of the buildings.

Examples of the above are shown in Appendix 1.

5.2 Digital Resource Systems Ltd.

Digital Resource Systems Limited (DRS) was formed in 1981 for the purpose of developing, selling, and supporting land management software solutions. DRS has over 300 clients worldwide using a variety of land management productivity tools. The company has experience in land management in Canada and the United States. Staff have extensive experience with survey and map-related applications of geographic information system requirements in Canada, the United States and Southeast Asia (Thailand and Malaysia).

The company's head office is located in Nanaimo, British Columbia. A branch office in Waterloo, Ontario was opened in December 1989. Digital Resource Systems currently has a staff of over 30, mostly professionals from diverse backgrounds including surveying and mapping, geology, forestry, computer science, and engineering.

The company's core product, TerraSoft offers a powerful set of mapping and analytical tools which can greatly enhance the ability of land/resource managers to quickly assess land use alternatives and make informed decisions. Marketing of TerraSoft is done both through direct efforts and authorized dealers and distributors.

Digital Resource Systems recently received the 1989 Award of Excellence from the Software Association of British Columbia in recognition of its achievements in the development and marketing of TerraSoft.

A PC-based GIS, TerraSoft provides pragmatic solutions that build on the user's acquired microcomputer skills. TerraSoft is noted for its natural user interface, flexibility, and transparent integration with popular third-party database managers such as dBase, Rbase and Oracle. It can be exported to PC programs such as Lotus 123 and Word Perfect.

With its multi-theme overlay capability, and its ability to utilize data from a variety of sources, TerraSoft can play a central role in EIA. Apart from handling both vector and raster polygons for fast analysis previews, the program can handle up to 255 layers for clear presentation of congested geographic data. Other facilities include 3-D terrain modelling (DTM), cartographic plotting capabilities, a screen image capture and playback utility and translators for standard industry graphics formats such as IGDS, ARC/INFO and AutoCAD.

TerraSoft is currently being used in 13 countries for applications in forestry, municipal management, hydrology, agriculture, environmental impact assessment, transportation, risk analysis, recreation planning, surveying and map production, regional planning, and land redistribution.

A full-featured GIS such as Terrasoft is not only a powerful tool, it can fulfil a central role in EIA. It can be easily combined with other tools (e.g., statistical, spreadsheet or graphics software) to provide different types of analyses and presentations.

Traditionally, the public review stage of an EIA is often hampered by bulky reports and the inability of the proponent to present data in a manner that is easily understood by the public. GIS can greatly improve the ability to convey relevant information to decision makers and the public, through both hard copy and interactive participation. Using a PC together with a large monitor or projection unit alternatives can be examined directly on a projection screen.

In addition to projects completed by Catherine Berris Associates using **TerraSoft**, demonstrations of other projects where environmental considerations have played a major role will be available at GLOBE 90. These include the following:

1. Sustainability Study of the Jhikhu Khola watershed in Nepal

This study, undertaken by Dr. Hans Schreir, Professor of Soil Science at the University of British Columbia utilized **TerraSoft** to analyze trends for the past 40 years in land use and soil erosion, and the implications of these trends for sustainability. The study used maps and demographic data dating from the original survey of 1947. Data from the Land Resource Mapping program sponsored by CIDA during the 1980s was evaluated and utilized. Current food, feed, and fuel wood inventory data from this program were used.

With the assistance of agricultural economist, Dr. George Kennedy, a model was developed, using Lotus 123, to arrive at a measure of sustainability by defining a poverty index and a supply-and-demand balance sheet for each district. Using **TerraSoft**, trends from the past, through the present and projections into the future were graphically displayed for the many different districts of the watershed.

This study has formed the basis of ongoing work to develop and implement the appropriate land use strategies and policies to achieve sustainability in the region.

Examples of this study are found in Appendix 2.

2. Transmission Line Routing Study in Southern Saskatchewan

This study, undertaken by Terrestrial Aquatic Environmental Managers for **SaskPower** Corporation,

evaluated eight alternative routes for a transmission line in terms of environmental and other constraints. A clear choice for the optimal route, with the minimum environmental impact, emerged from this analysis.

5.3 Environmental and Social Systems Analysts (ESSA)

ESSA is a research and development firm dedicated to the development and implementation of creative solutions to environmental problems.

ESSA was incorporated in 1979 by three systems ecologists associated with the Institute of Animal Resource Ecology at the University of British Columbia. They sought to make the quantitative techniques of systems analysis available to the fields of environmental and social research, assessment and management. During the past ten years, ESSA has completed over four hundred projects for corporate and government clients in North and South America, Europe, Southeast Asia, Australia and Africa. In Europe, ESSA's partner is Hintermann and Weber, a resource management and planning consulting firm located near Basel, Switzerland. ESSA has offices in Victoria, Toronto, Bangkok, Thailand and a head office in Vancouver.

ESSA provides unique integration of scientific expertise, rigorous systems analysis techniques (such as computer simulation, expert systems, GIS, mathematical models, database design/management, statistical analysis and policy exercises) and proven communications expertise (such as audiovisual presentations, training workshops, conferences, conflict resolution and structured, problem-solving workshops) for creative and comprehensive issue resolution.

ESSA's wide-ranging experience includes research planning, monitoring and management in fisheries, forestry, wildlife and agriculture; researching, assessing, and predicting the environmental and social impacts of acid rain, stratospheric ozone depletion, and global climate change; and designing policies, tools, and procedures in support of integrated environmental impact assessment.

ESSA's researchers and scientists make extensive use of the most recent available computing technology for software development, modelling, analysis and document preparation. Project Development occurs in close collaboration with clients to develop a product that is most useful to their needs.

ESSA offers four main types of computer applications: geographic information systems; computer and mathematical modelling; expert systems; and statistical analysis. The following are examples of how these applications are used for project development.

Geographic information systems (GIS) have become an important tool for land and resource management and their use is expanding rapidly as more spatial information is being digitized and obtained from aerial and satellite photography. While both GIS and expert systems are being developed and used more widely, they are in general being used independently. At present, there are no general interfaces between expert systems and GIS that can be used to develop systems that combine the benefits of both approaches. Over the next two years, ESSA will be addressing the development of this missing link. The combination of these two technologies will provide a mix of expert systems and GIS which would give the user of the overall system an intelligent decision making tool, the usefulness of which would be much greater than the sum of the two parts.

Computer and mathematical modelling. ESSA's strength in the environmental consulting field can be defined by our ability to apply a number of different computer applications to our projects and proposals. This expertise in resource modelling has often been in conjunction with interdisciplinary workshops. Some projects have involved the development of impact hypothesis to aid in the design of monitoring programs, while in others, simulation models were constructed to help evaluate the implications of development and management options. Recent clients that have benefited from this technology include: Mekong Secretariat, Vietnam; Northwest Power Planning Council; U.S. Fish and Wildlife Service; Canadian Wildlife Service (CWS), and Organization of Eastern Caribbean States.

ESSA's work in **statistical analysis** ranges from the structuring and analysis of simple datasets to complex data analysis requiring the development of customized programs. Programs are designed using information relevant to each project and most appropriate to the client's needs. Completed projects requiring statistical analysis include: a mesoscale lake survey for the Department of Fisheries and Oceans; a dose-response framework for the 1990 NAPAP assessment for the U.S. EPA; and a regional model of acidification effects on waterfowl for the CWS.

Since 1987, ESSA has had an internal research and development program aimed at the production of expert system tools for environmental assessment, planning and review. In the course of this research program ESSA developed a framework for handling environmental impacts in expert systems that can be generalized to many different applications.

2. SCREENER Expert System

SCREENER has been designed for application within EARP. As such, its features have been tailored to meet the special requirements of EARP. Basic features of the system allow it to determine the appropriate FEARO screening code; provide the associated rationale for the screening decision; and list mitigation, monitoring, or information requirements as necessary.

Advanced features designed into the system are flexible options to allow the user to select the desired level of detail in reporting; automatic updating of the screening registry database used for quarterly reporting for FEARO; a past-screening decisions database to allow the user access to past-screening decisions and review them for their applicability to the present project being screened; and the ability to save and recall site specific environmental information for use in future screenings of project on the same or similar sites.

This system presents the following advantages to environmental managers across Canada:

- A. It will lessen the burden on managers and their staff. SCREENER will allow a large number of proposals to be screened each year and will provide to less skilled professionals the tool for high-level environmental assessment.
- B. It will accomplish screening more efficiently in terms of time and money.
- C. It will promote consistency in screening decisions.
- D. It will ensure a more effective implementation of the environmental assessment process, thereby reducing the potential for project delays and cost overruns due to unforeseen environmental concerns.

SCREENER is an interactive, user-friendly system. Users require minimal computing experience in order to operate it.

In addition to SCREENER, ESSA has designed similar expert systems for a number of clients. Variations on the theme of SCREENER have been produced for the U.S. EPA, Transport Canada, Environment Canada, Parks Canada Service, Canadian Coastguard, Canadian Forest Service and Great Lakes Fishery Commission.

An example of Screener is shown in Appendix 3.

5.4 S.L. Ross Environmental Research Ltd.

S.L. Ross Environmental Research Limited is an internationally recognized consulting firm specializing in oil and chemical spills and their control, and geographical information system (GIS) database development and spatial modelling. Particular areas of expertise include:

- research and development of environmental impact assessment methods
- assessment of environmental impacts associated with marine transportation and offshore oil and gas activities
- computer modelling of oil and chemical spill behaviour and fate
- environmental studies using GIS

The oil spill impact assessment system developed by S.L. Ross is an example of the integration of oil fate and impact assessment software with a state-of-the-art microcomputer based GIS.

1. Computer Applications to EIA by **S.L. Ross**

Tydac Technologies' Spatial Analysis System (SPANS) is used to handle the spatial requirements in this system. An in-house oil-fate prediction model is directly linked with the GIS software as a user function to allow access by the oil fate model to spatially mapped data such as land mass location and water currents, and to permit the output of an oil distribution map in a GIS format. The real-time impact assessment system automatically calculates the oil's trajectory, distribution, and properties; overlays the resulting map onto the resources in the vicinity of the spill; then calculates the percent of each resource at risk from the oil spill. The system has been automated such that the end-user does not have to know how to operate the GIS system; it is simply utilized in the process when needed. Because the GIS handles all of the spatial requirements, the impact assessment tool can be implemented in any geographic location by simply mapping the new coastline and resource base of interest. The current application was developed for the U.S. Gulf of Mexico. The method used for oil spills has other parallel applications in fate and effects modelling such as in air dispersion and soil contamination problems.

2. Impact Assessment Model

The model estimates the impact of an oil spill as follows. A map of oil fate and movement is generated showing predicted locations and concentrations of oil at various times after the discharge. Oil fate data is combined with resource-specific toxicity data to determine the size and location of areas of toxic conditions or areas of effect (AOEs) for each resource. AOEs are compared with the historical spatial distributions of each resource at the time of year of the spill to estimate the proportion of stocks and fisheries that may be at risk from the spill. This estimate is then corrected for the influence of other spatial, temporal, and biological factors (e.g., population age-structure) to yield an estimate of spill impact on all resources and fisheries.

3. List of key environmental resources

There are thousands of species of resources in the biological communities of the Gulf of Mexico and it was not practical to compute impact on all of these. With the cooperation of representatives of the five Gulf states, a representative list of 70 resources has been compiled that includes representatives of all oil-sensitive groups and all major ecologically or economically important resources, major habitat-types, model representatives of other oil-vulnerable groups, endangered species, and species of local concern.

4. Oil fate: Hybrid SPANS/S.L. Ross Model

A key element of the impact analysis is the ability to predict oil fate and movement as a function of time after discharge. The surface slick thickness, volume left on the surface, sub-surface hydrocarbon concentrations and physical properties of the oil are needed to determine whether resources exposed to oil may be adversely affected. The oil spill fate model used accounts for all the major oil fate processes of advection, spreading, evaporation, natural dispersion, and emulsification. The model generates dimensions and thicknesses of oil slicks and slicklets, oil properties, and dispersed oil concentrations as a function of time after discharge. This model has been tested against major oil spills that have been adequately documented, and the correlations are good.

After the oil fate and trajectory analysis is completed,

this oil spill information is combined with the resource database to determine spill impacts.

An example of the above oil spill model is shown in Appendix 4.

5. Vulnerability of resources

Populations of certain resources are widely distributed over large areas. Even though individual members of such populations may be at risk from spills, these individuals **may** represent only a very small proportion of their respective populations. Other resources, on the other hand, are highly aggregated in a limited number of specific locations. If oil enters these areas, the risk of significant effects to these populations is high. The historical data on the distribution and aggregation patterns of resources (and hence the vulnerability to spills) are depicted using distribution maps stored in the SPANS GIS. These maps represent the distribution of each resource, identify sub-populations or stocks, and show the location, size, and density of any areas of aggregation. For resources in which certain life stages (eggs, larvae, juveniles) differ dramatically from adults in their habits or when habits or distributions of any given life stage change seasonally, each life stage and/or seasonal distribution is mapped separately. A total of over 400 maps are required to **characterize** the 70 resources modelled in the Gulf of Mexico application.

Appendix 4 provides a model of the distribution of adult red snappers in the Gulf of Mexico.

6. Impact algorithms

The location and extent of the AOE resulting from a spill are mapped using the "hybrid" model and then compared with the distribution maps of the target population, to estimate the proportion of the population that may be at risk from the spill. The comparison is made by creating a SPANS "unique conditions overlay" of all of the appropriate maps needed in the final analysis. A text report that itemizes the combinations of attributes from these map layers is also generated by SPANS. Estimates of spill impact on resources are then computed by a series of resource-specific impact assessment algorithms that **utilize** the information from the unique conditions report and data concerning the sensitivity and vulnerability of resources. Because of the different kinds of interaction between oil

and resources, unique algorithms were developed for each resource.

7. Relative importance of resources

Any dispersant decision must take into account not only the impact of oil on resources, but also the relative importance of the resources to the local human population. In a system such as this, the "relative importance" question might be handled in a number of ways ranging from a rigid quantitative ranking scheme based on socio-economic and ecological criteria, to a completely unstructured subjective system. In the Gulf of Mexico model system the state representatives decided to assess the relative importance of resources subjectively at spill time, based, in part, on economic and other data that are documented as part of the system.

8. Summary of impact assessments

Once the effects of treated and untreated oil have been computed for all resources, these results are summarized so that the user can quickly determine whether dispersants can reduce the overall effect of the spill. A comparison of risks is made by listing, side-by-side, the predicted effects of the treated and untreated spills on the key resources. The user can then, on the basis of these estimates of impact and assessments of importance, prepare arguments both in favour and against the use of dispersants, and can quickly formulate a logical and defensible decision regarding dispersant use.

9. Documentation

One of the most important concerns of a decision-maker who is dealing with the dispersant problem is documentation. The decision maker legitimately requires detailed documentation of the dispersant decision for justifying and defending the decision to superiors, the press, interested parties, and the public at large. In this regard the system has been designed to provide, on demand, details of impact calculations for each resource (effects on lifestages and fisheries), as well as the biological and toxicological input and the oil fate data that went into the impact calculations.

10. System Operation

One of the major requirements of this system is that it had to be able to quickly (within an hour or so) evaluate the potential impact from an oil spill and do so with minimal operator input and interaction. This is accomplished through the use of the "hybrid" oil fate/GIS software and other software developed in-house, which permits the unattended operation of the SPANS GIS. A menu driven "front-end" has been developed to prompt the user for spill characteristics and environmental conditions necessary to run the impact model. After the user enters the needed data, the system operates to completion without further operator intervention.

5.5 Pegasus Consulting Group

Today's business and resource development problems are complex and their solution requires a multi-disciplinary approach. The Pegasus Consulting Group offers biological, economic, planning, management, and information services that are designed to solve these problems.

The Pegasus Consulting Group, a partnership of corporations, is comprised of resource development companies, major consulting organizations, and government. Pegasus can help clients take advantage of opportunities to apply computer technology to deal with business and resource development issues through the following information technology services:

- User-needs analysis and the evaluation of system alternatives
- Development of databases for use with GIS (mapping) systems
- Software package evaluation and implementation
- End-user training and support
- Desktop publishing

Pegasus, through one of its partners, Keir & Muller Associates Inc., is demonstrating mapping and GIS work from a full environmental assessment of a planned generating station for Ontario Hydro on the Niagara Peninsula, Ontario.

The project that will be the basis of the Pegasus demonstration at the GLOBE 90 conference is the proposed 1.3 billion Sir Adam Beck 3 project located in Niagara Falls, Ontario. It involves the development of a new 1050-megawatt generating station on the Niagara River some 10 kilometres downstream from the Falls. Water for the plant will be conveyed to the station via two underground

tunnels that start up-river from the Falls and run underneath the city of Niagara Falls to emerge at a reservoir located on top of the gorge above the proposed power station. The tunnels will be approximately 13 metres in diameter and at their deepest point will be some 200 metres below grade. Construction is proposed to start in 1992 and completion is scheduled for 1998.

Work on the project, in conjunction with Acres International, involves the preparation of a full project environmental assessment. As a means of portraying baseline conditions and identifying and analyzing impacts, Pegasus has been using a variety of programs on Macintosh computers to develop intelligent maps to portray engineering, natural environment, and socio-economic information. Chloropleth maps were constructed for the study area showing the land use fabric. Demographic and community data was compiled in a database and subsequently used to construct social area maps. Isopleth maps were constructed for noise and dust data and a series of thematic and quantitative maps, some of which were integrated with a database, were developed for natural environment and socio-economic data. Engineering drawings were developed via CAD applications and entered into various map bases.

An example of the above is shown in Appendix 5.

5.6 TYDAC Technologies

Established in 1982, TYDAC Technologies specializes in the development of GIS software and related applications. TYDAC's main product, SPANS, is designed for professionals who require stand-alone desktop workstation with strong data integration, analysis and modelling capabilities.

A pioneer in the use of the quadtree structure, SPANS can rapidly process complex geographically referenced databases in all three key data structures (vector, raster, and quadtree), along with images of varying resolution.

At present, more than 600 SPANS systems have been installed in over 30 countries. Environment Canada has over 50 SPANS in use throughout the Canadian Wildlife Service, Canadian Parks Service, and Inland Waters Directorate. The St. Lawrence Centre is using SPANS in its clean-up work on the St. Lawrence River, and the International Joint Commission has actively utilized SPANS in its recent investigation of the impacts of fluctuating water levels in the Great Lakes.

Approximately 75% of TYDAC's SPANS systems are exported, primarily to the United States, United Kingdom, Southeast Asia and Australasia. TYDAC has offices in Ottawa, Washington, D.C., London, England, and Bangkok, Thailand.

In November 1989, TYDAC Technologies won the Silver Award in Innovation in the Canada Business Awards of Excellence. TYDAC technologies has developed the following computer applications:

Proposed Low-Level Training Facility at Goose Bay, Labrador

The Department of National Defence (DND) has purchased SPANS for its Canadian Forces Base (CFB) at Goose Bay, Labrador. An environmental impact statement has been prepared by DND as part of the federal environmental assessment and review process, assessing the effects of low-level training flights that originate from CFB Goose Bay. Each year, NATO countries including West Germany, The Netherlands, and Great Britain conduct approximately 7,000 of these flights in a training area of 100,000 square kilometres.

Using a 500,000 square kilometre area in Eastern Quebec and Labrador, SPANS is being used to integrate and analyze information regarding land use, noise and air pollution, wildlife, and socio-economics in order to minimize any negative impacts of low-level flying on the environment and the users of the area. From these analyses, SPANS will be used to generate constraint maps that will indicate which areas should be completely avoided, under monitored avoidance, or designated as free flying zones.

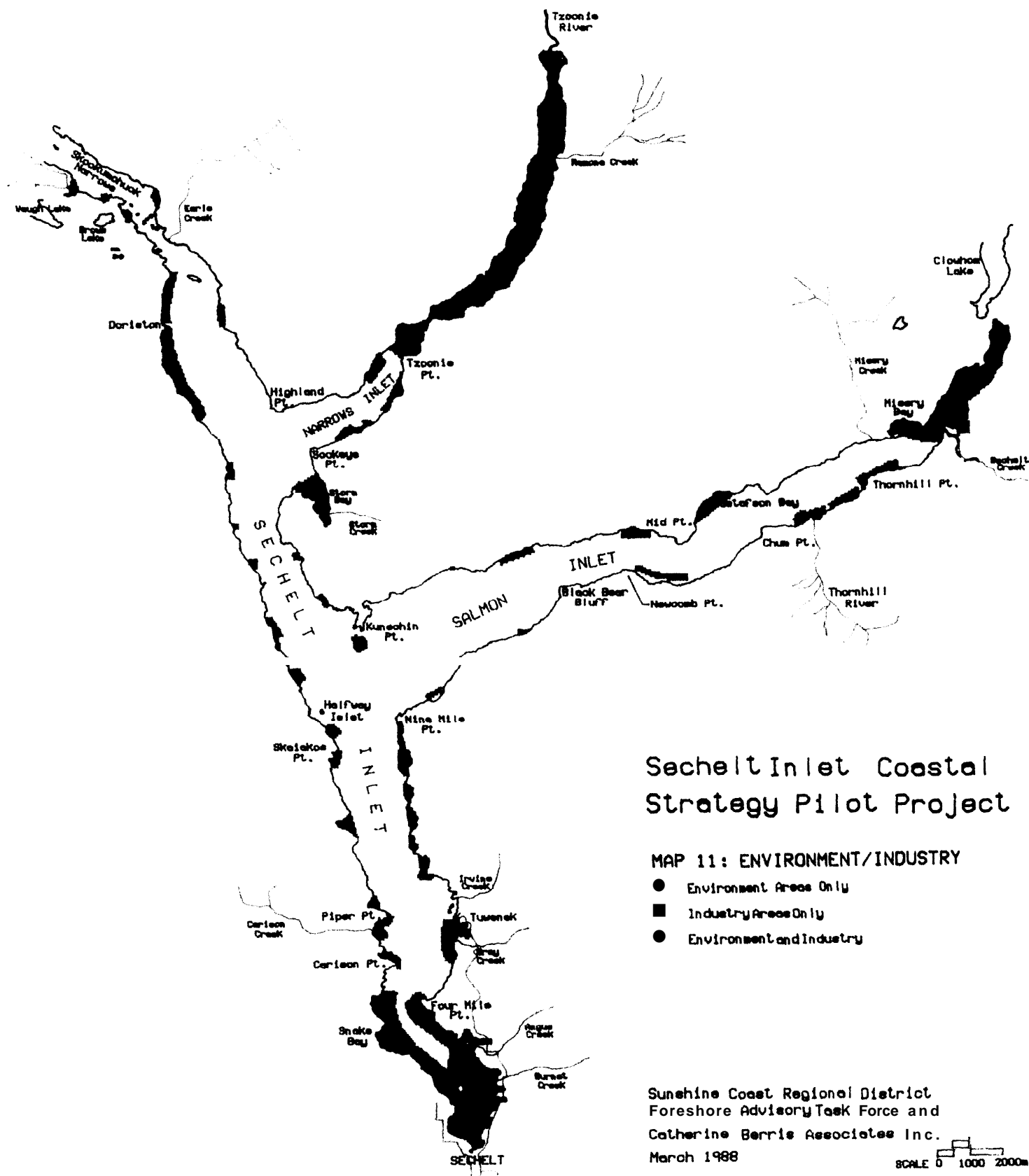
SPANS will also be used in DND's on-going discussions with native peoples to review issues of concern such as hunting and fishing areas and camp locations.

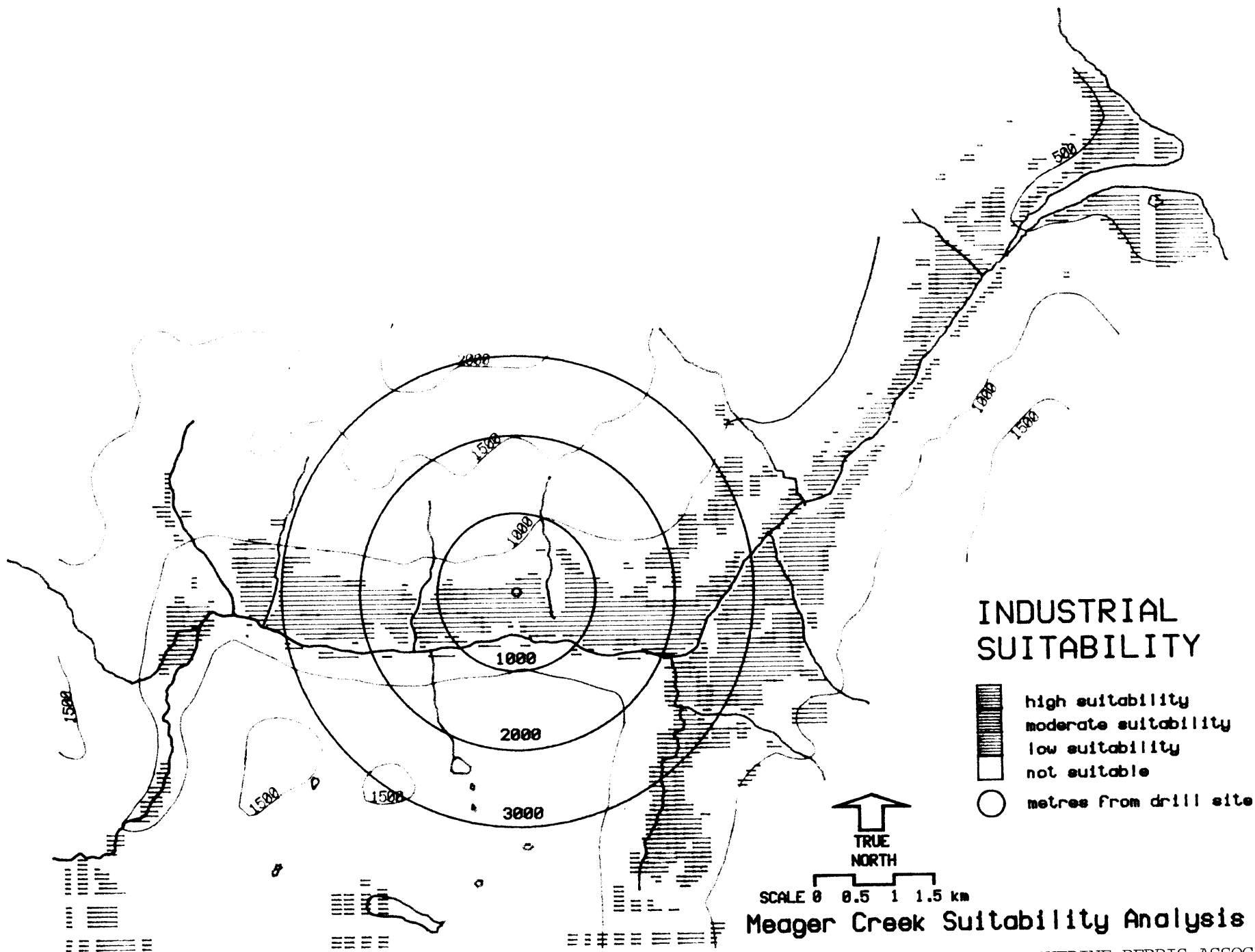
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1. Initial Assessment Guide, Federal Environmental Assessment and Review Process. Federal Environmental Assessment Review Office. Ottawa, Ontario. April, 1986.
2. The Federal Environmental Assessment Review Process. Federal Environmental Assessment Review Office. Ottawa, Ontario. 1987.
3. Gray, Alan and Stokoe, Peter. Knowledge-Based or Expert Systems and Decision Support Tools for Environmental Assessment and Management. Their Potential and Limitations. Report for the Federal Environmental Assessment Review Office. Ottawa, Ontario. November, 1989.
4. LeBlanc, P.J. Environmental Assessment as a Integral Part of Decision-Making. Presented at a Senior Management Orientation Course. November, 1988.
5. LeBlanc, P.J. Environmental Impact Assessment and Information Needs. Presented at a Forum on the Inland Waters, Coastal and Ocean Information Network (ICOIN). 13-14 June, 1989. Fredericton, New Brunswick.

APPENDIX 1

CATHERINE BERRIS AND ASSOCIATES



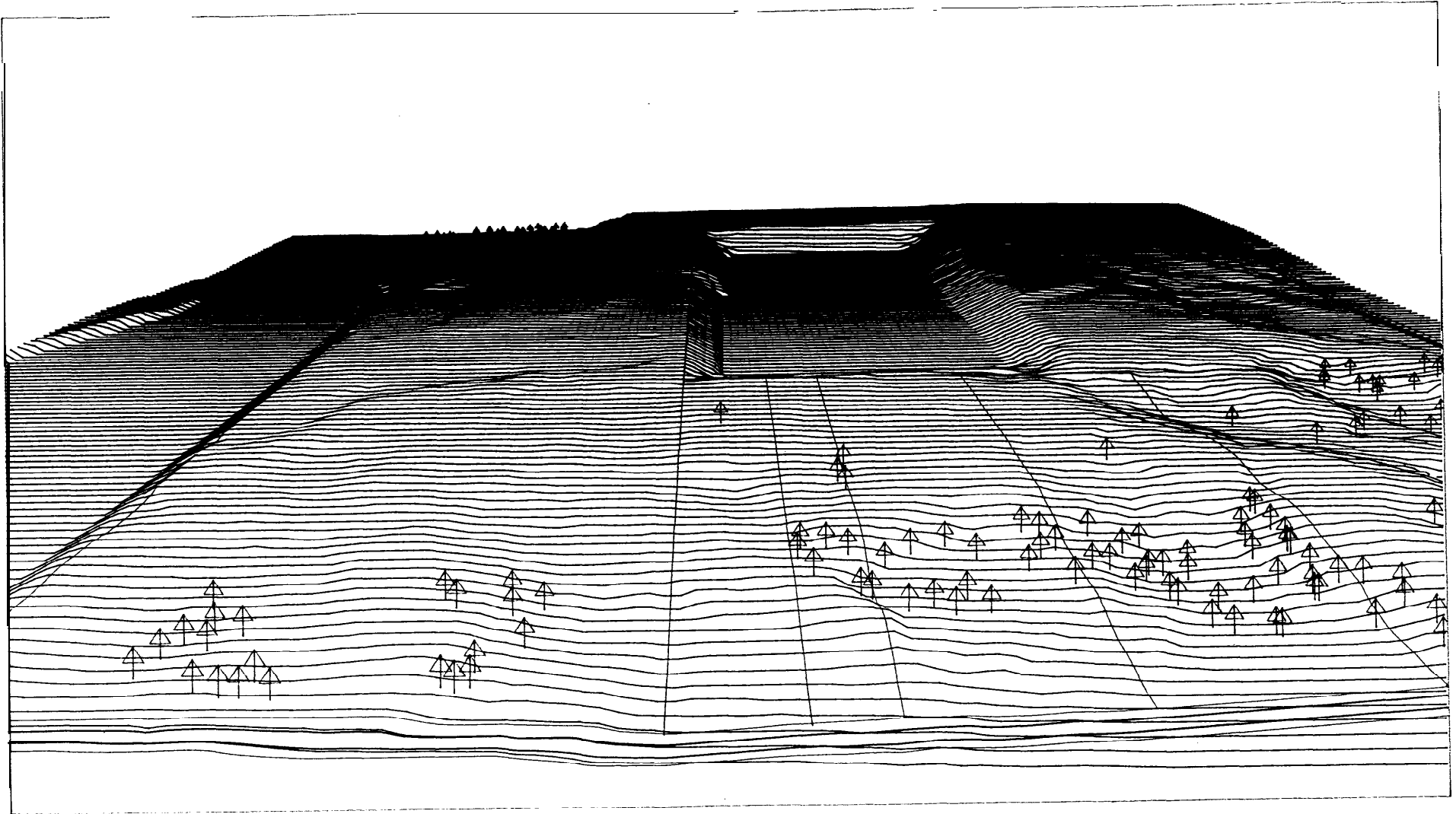


Meager Creek Suitability Analysis

CATHERINE BERRIS ASSOCIATES

PROPOSED MATSQUI GRAVEL PIT
Aerial view from south of the site

Phase 1:
current proposal half completed





Scene which contains proposed cutblocks



Computer-generated perspective superimposed on scene: green areas are proposed cutblocks and symbols show average tree height

CATHERINE BERRIS
ASSOC.

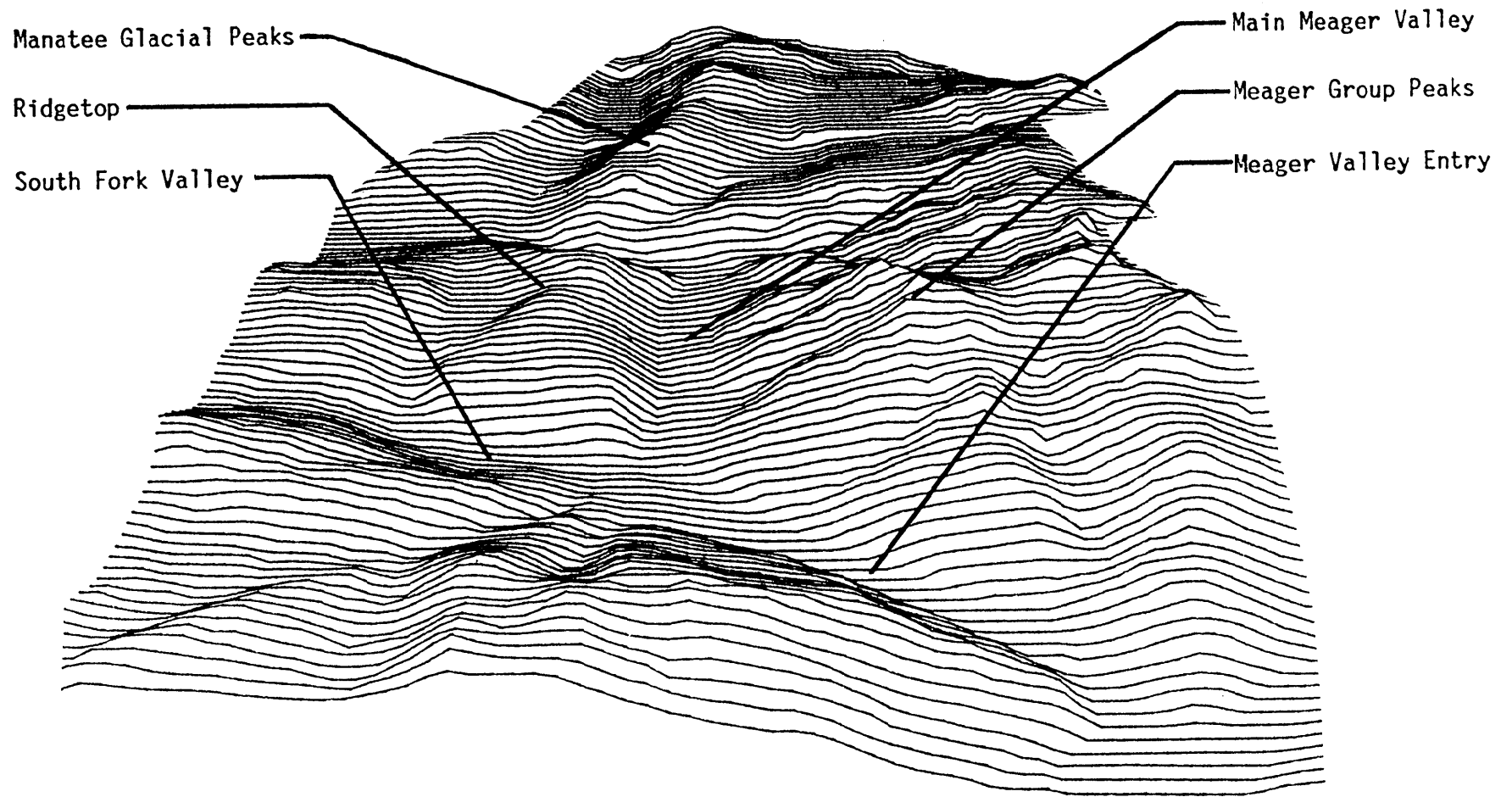


Simulation of clearcuts in cutblocks



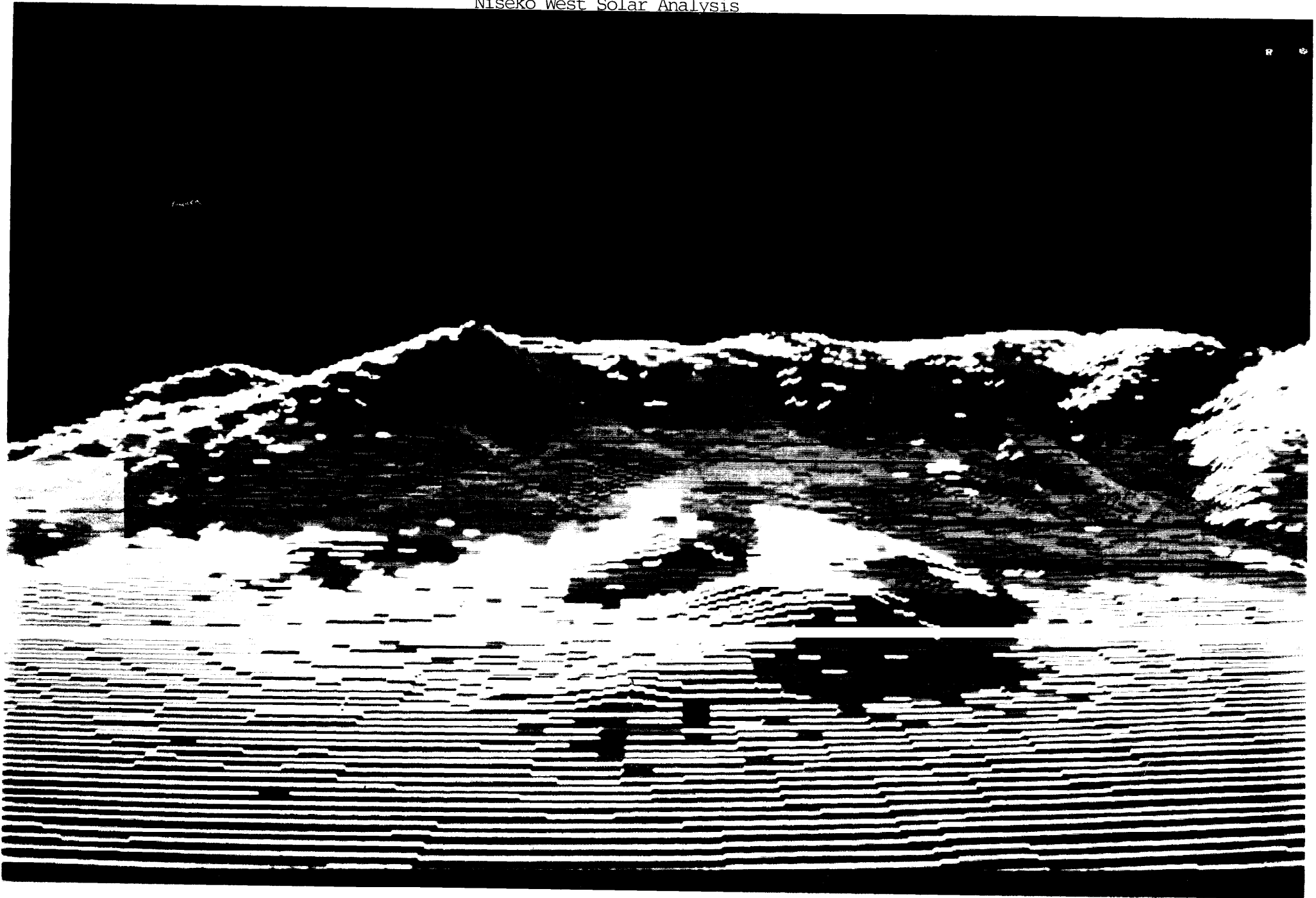
Simulation of green-up in cutblocks

Meager Creek Suitability Analysis



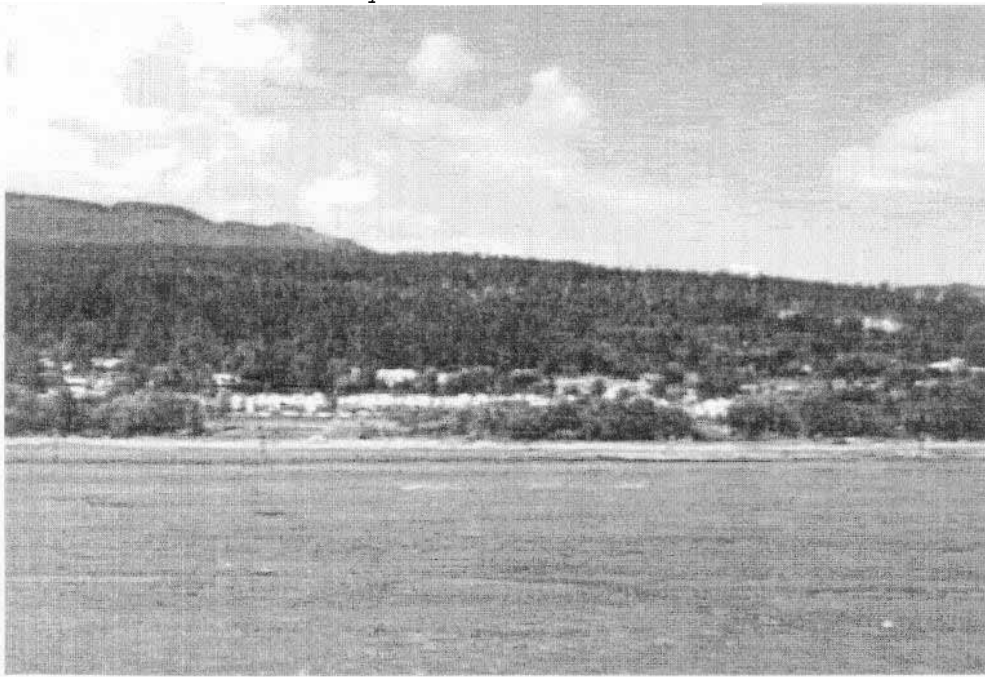
Computer sketch of the Meager valley looking west

Niseko West Solar Analysis

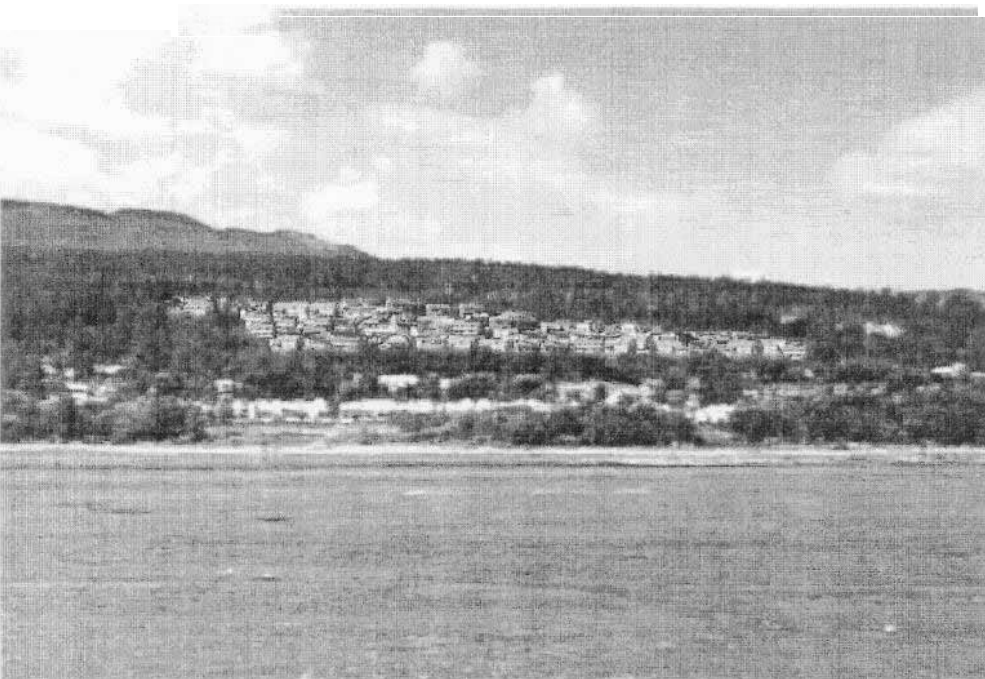


CATHERINE BERRIS ASSOCIATES

Port Moody North Shore Simulations

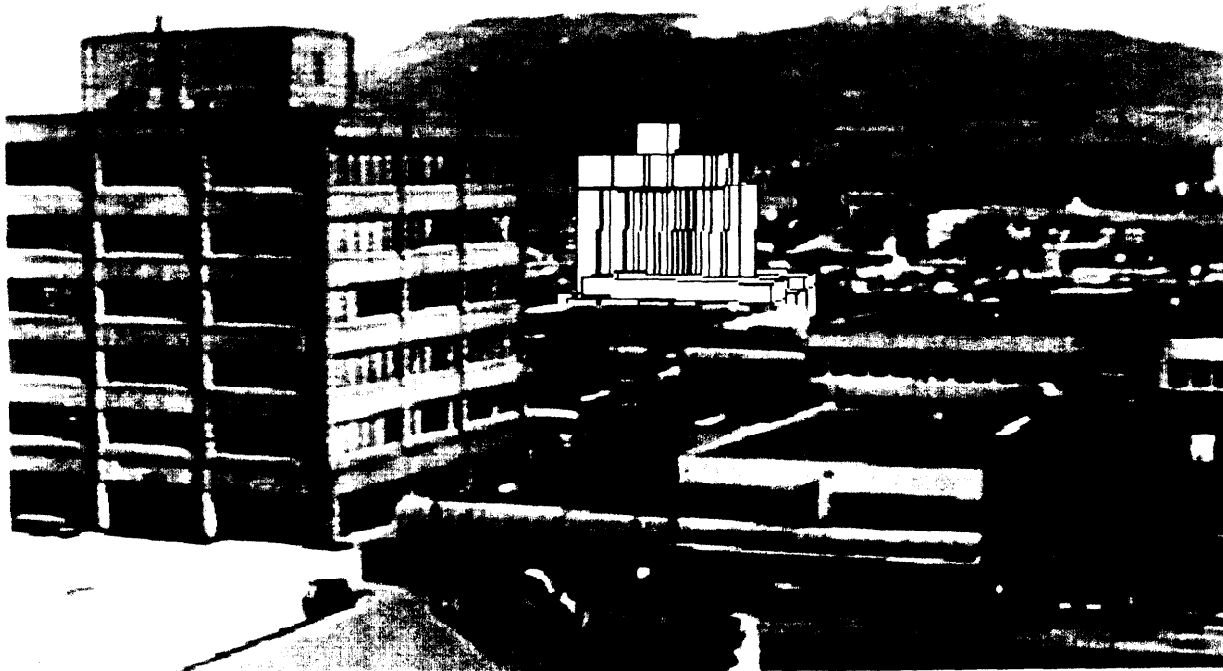
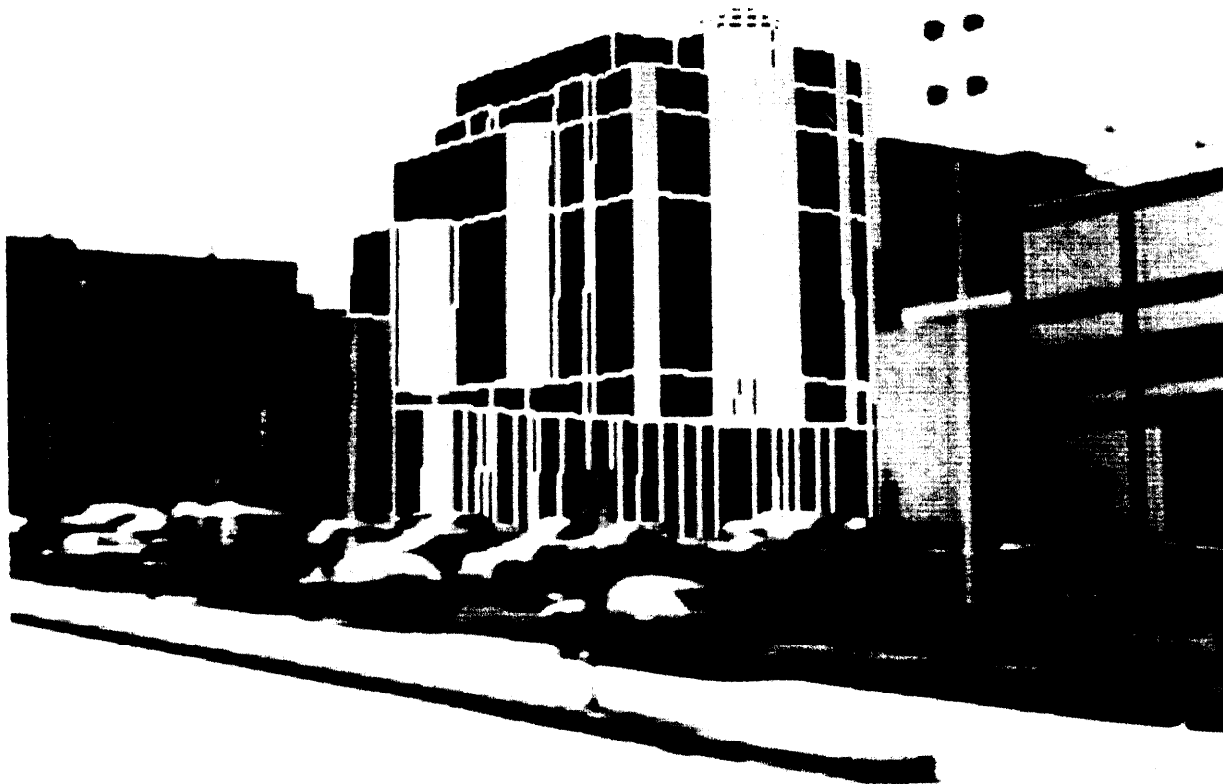


Existing view including Parcel 2 of Heritage Mountain



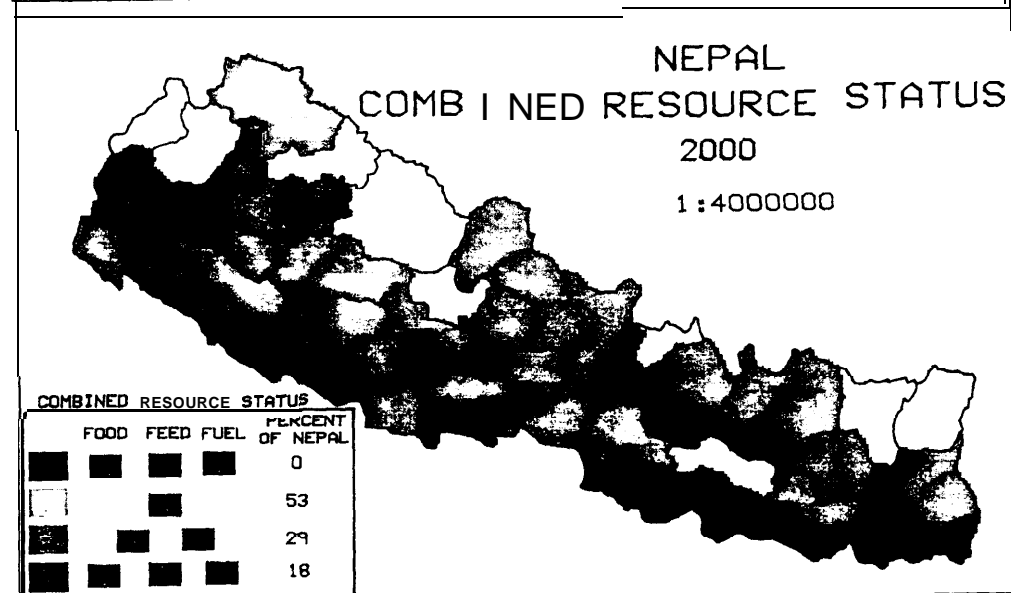
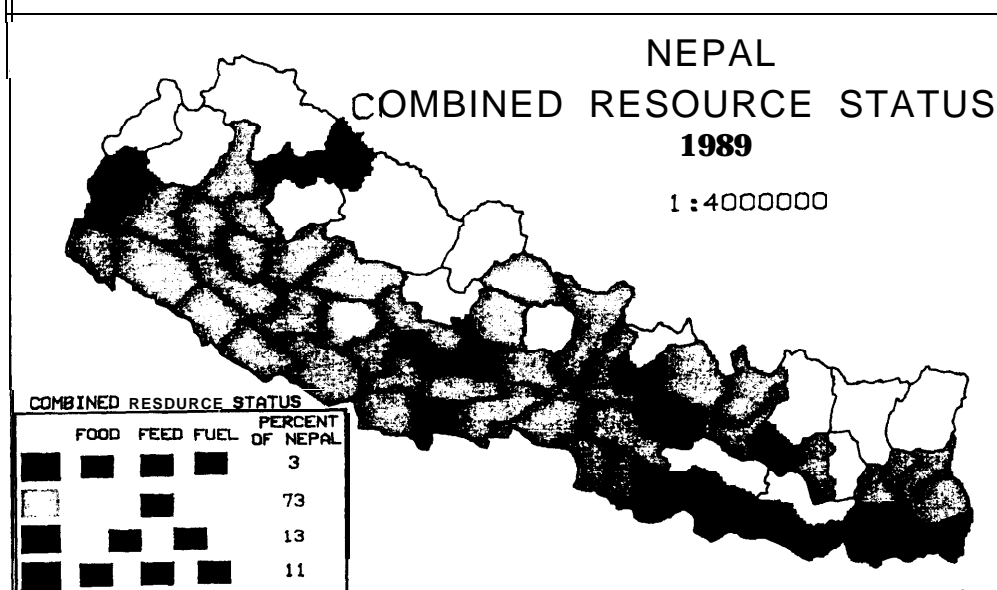
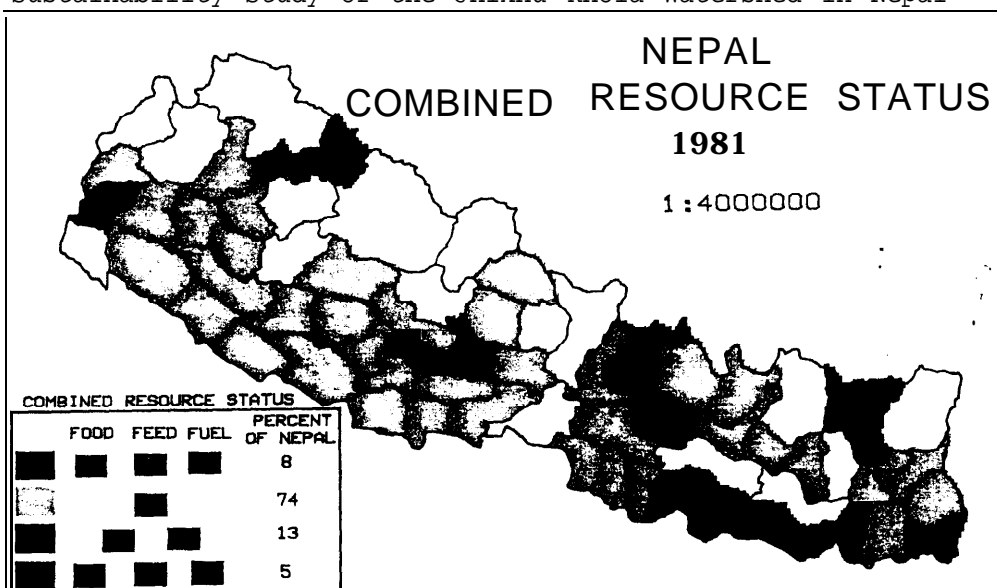
Simulation of proposed development of Heritage Mountain

Urban High-Rise Visual Impact Assessments

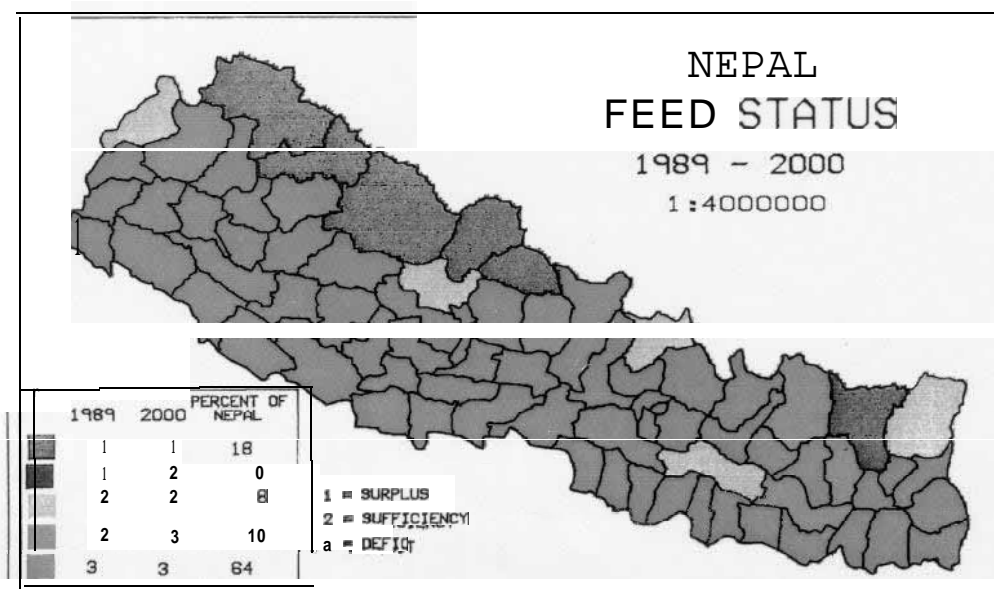
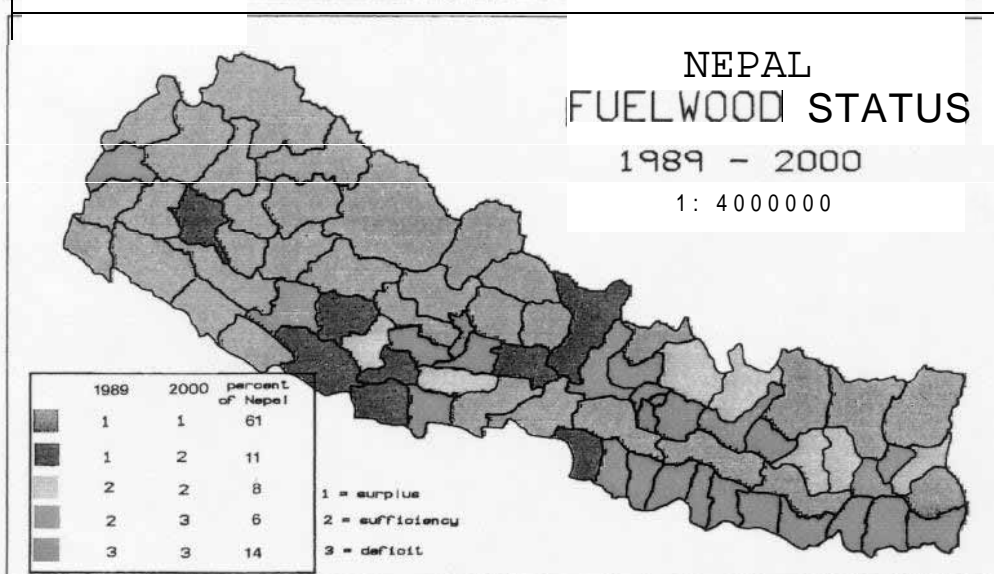
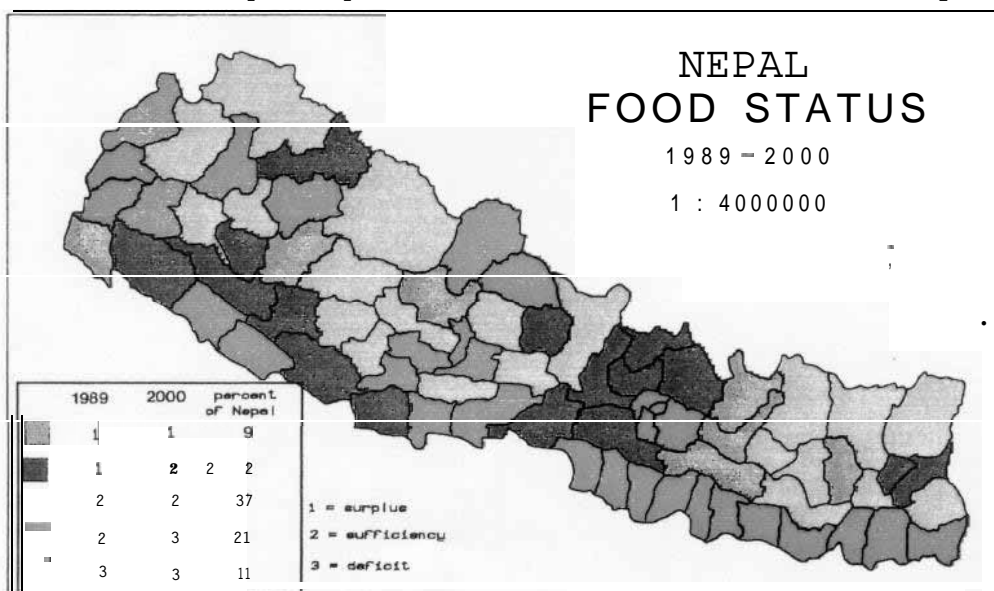


CATHERINE BERRIS ASSOCIATES

APPENDIX 2
DIGITAL RESOURCE SYSTEMS

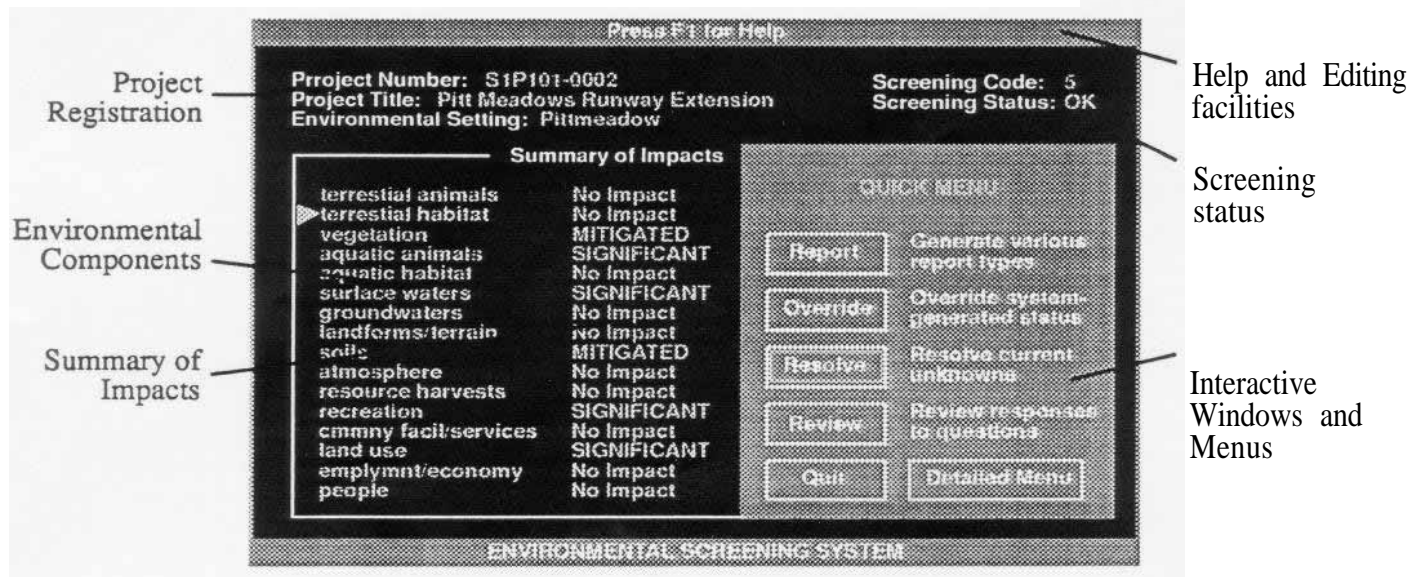


Sustainability Study of the Jhikhu Khola Watershed in Nepal

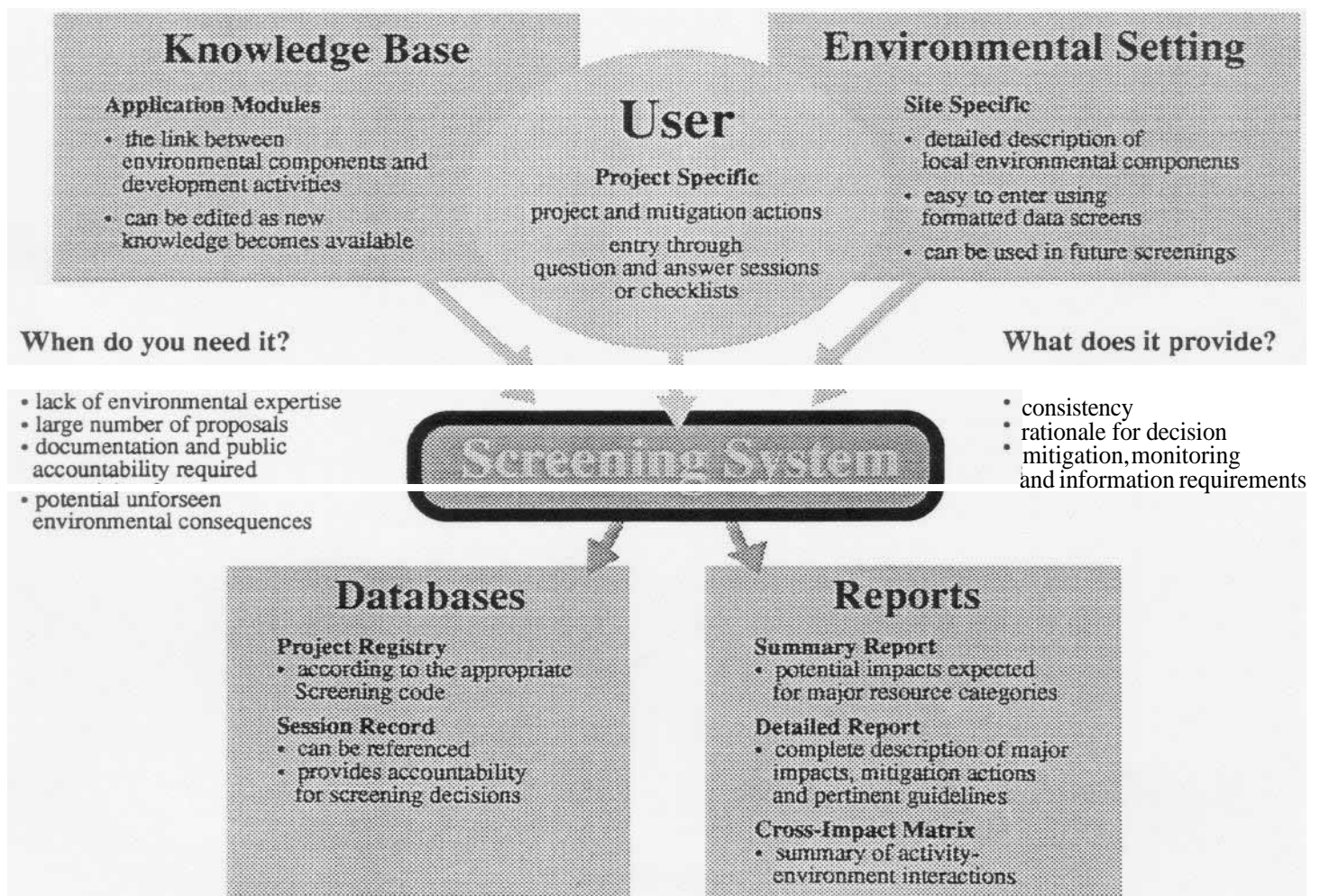


APPENDIX 3
ENVIRONMENTAL AND SOCIAL SYSTEMS ANALYSTS

Concerned about Environmental Impacts?

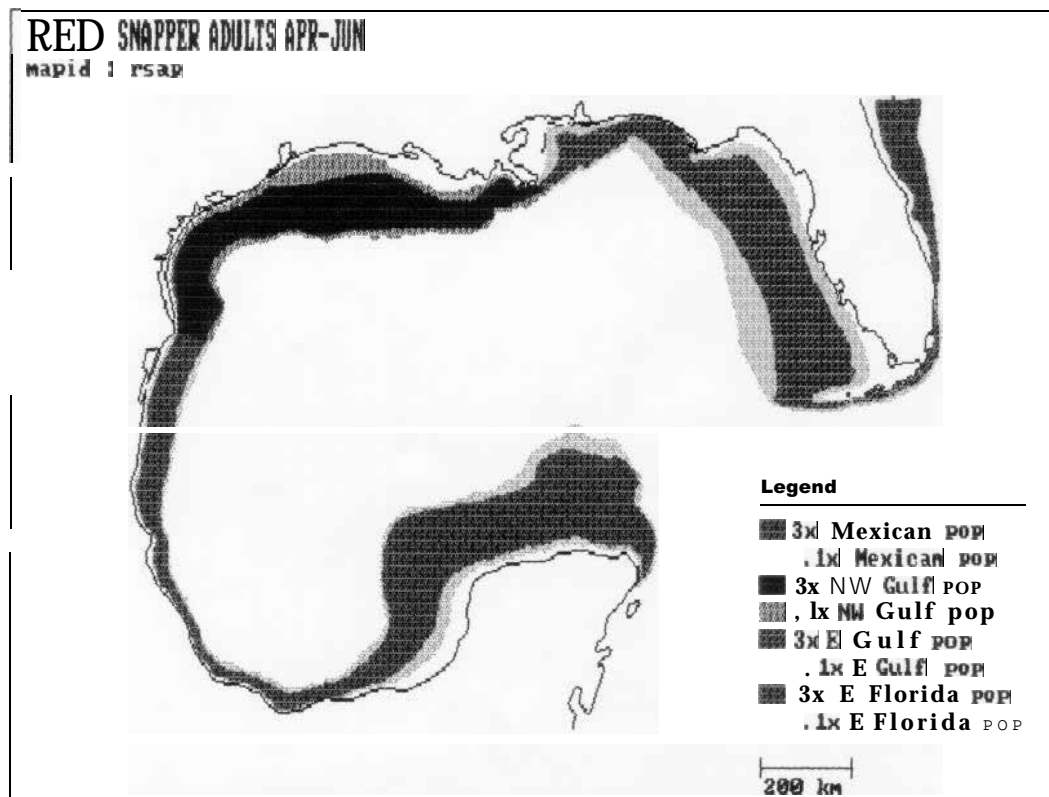
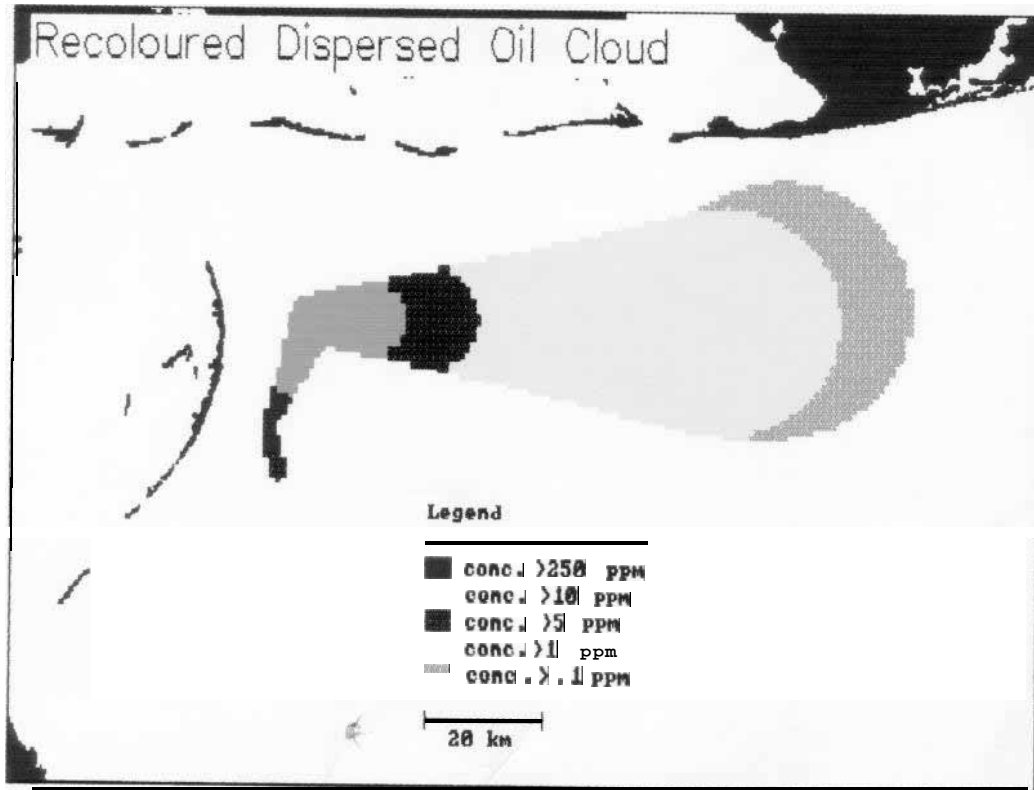


Introducing SCREENER An Expert System for Environmental Assessment



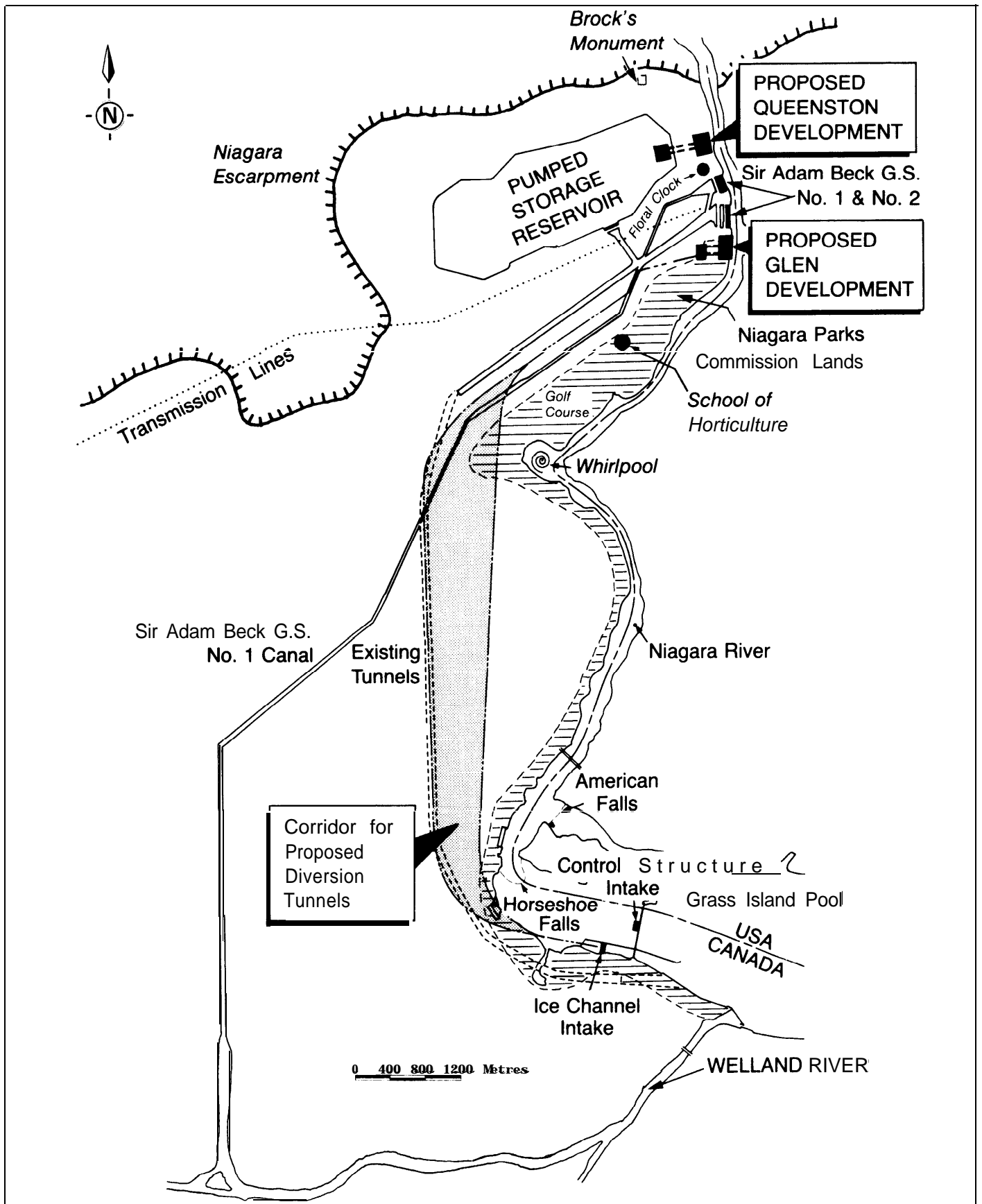
APPENDIX 4

S.L. ROSS ENVIRONMENTAL RESOURCES LTD.



APPENDIX 5

THE PEGASUS CONSULTING GROUP



Niagara River Hydroelectric Development Glen and Queenston Alternatives

two, three, and four 275 MW units were considered for the Glen development.

The proposed Glen development would be operated in conjunction with the existing SAB facilities to optimize power and energy output for power generation. Storage capacity available in the Grass Island Pool (about 6 million m³) and the SAB PGS reservoir (about 21 million m³) would be used completely every day to maximize the transfer of water available during nighttime hours for power generation during the daytime hours. The existing SAB PGS would operate in the pumping mode each night to refill the reservoir. During the daytime period the SAB PGS would operate in the generating mode to provide peak power output and supplement diversion flow for use by the existing SAB No.1 and No.2 stations as well as the proposed Glen generating station.

From an economic point of view, the two-unit 550 MW scheme, including additional diversion capacity of 700 m³/s, is the most attractive Glen alternative. Estimated net average annual energy output for this combination is about 800 GWh, or 800 billion kilowatt-hours per year. Discharge capacity to the lower Niagara River would increase by about 720 m³/s for the two-unit installation.

Queenston Development Scheme

The Queenston development concept incorporates headworks located within the existing SAB PGS reservoir dyke, penstock tunnels about 10 metres in diameter, and a powerhouse located downstream from SAB No.1. This proposal would develop the head available between the SAB PGS reservoir and the lower Niagara River. The available head would range from about 116 metres to 107 metres and would average about 112 metres. The SAB PGS would be used primarily to refill the pumped storage reservoir each night. The stored water would then be discharged through the Queenston powerhouse during the daytime period when electricity demand is greater.

Generation capacity for the Queenston development concept is relatively independent of the diversion capacity available because of the large storage volume available in the existing SAB PGS reservoir. Additional diversion capacity, however, is an integral part of the proposed Queenston development con-

cept. Benefits of this additional flow diversion capability would be realized at the existing SAB stations as well as the Queenston development. Evaluations of two, three, and four 350 MW unit installations have been considered for the Queenston development concept. The two-unit installation (700 MW) would have a discharge capacity of about 720 m³/s and generation would extend over a period of about 8 hours per day. The three-unit installation (1050 MW) would use the SAB PGS reservoir storage capacity of 21 million m³ in just over 5 hours; discharging water at a rate of about 1080 m³/s. Based upon the feasibility study results, the two-unit and three-unit Queenston alternatives have both been retained for further consideration.

Net average annual energy output for the proposed Queenston development, including additional diversion capacity of 700 m³/s, is estimated to be about 1030 GWh. This is nearly 30 percent greater than the net energy output gain estimated for the corresponding Glen development. The higher net energy output of the Queenston concept results from a marginal increase in net head and the removal of hydraulic inefficiencies attributable to operation of the SAB PGS in its generation mode.

Future Activities

Before identifying a preferred alternative for the Niagara River Development, Hydro's project team will study the possible effects of both proposals on the natural and social environment. The team will be working closely with government agencies, conservation and other special interest groups, as well as members of the public.

Each alternative will be evaluated based on cost, energy output, technical aspects, effects on the natural environment and local communities. The evaluation will be assisted by comments from all levels of the government and the public.

This evaluation will lead to the identification of the preferred alternative. Where appropriate, measures to minimize environmental effects and disruption to the community will be proposed.

Results of the assessment will be documented in the Environmental Assessment (EA), which will then be submitted to the Ministry of Environment early in 1991. A decision on the approval is anticipated by late 1992.