Development Of An Integrated Bio-Economic Planning System For Corps of Engineers' Planning Projects: Conceptual Design

by

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Preface

The work reported herein was conducted as part of the Evaluation of Environmental Investments Research Program (EEIRP). The EEIRP is sponsored by the Headquarters, U.S. Army Corps of Engineers (HQUSACE). It is jointly assigned to the U.S. Army Engineer Water Resources Support Center (WRSC), Institute for Water Resources (IWR), and the U.S. Army Engineer Waterways Experiment Station (WES), Environmental Laboratory . Mr. William J. Hansen of the IWR is the Program Manager, and Mr. H. Roger Hamilton is the WES Manager. Technical Monitors during this study were Mr. John W. Bellinger and Mr. K. Brad Fowler, HQUSACE. The Field Review Group members that provide overall Program direction and their District or Division affiliation are: Mr. Bruce D. Carlson, St. Paul; Mr. Glendon L. Coffee, Mobile; Ms. Susan E. Durden, Savannah; Mr. Scott Miner, San Francisco; Mr. Robert F. Scott, Fort Worth; Mr. Clifford J. Kidd, Baltimore; Mr. Edwin J. Woodruff, North Pacific; and Dr. Michael Passmore, Walla Walla.

This report was prepared as part of the EEIRP work unit entitled "Environmental Databases and Information Management," directed by Mr. Bruce M. Sabol, Environmental Characterization Branch (ECB), Environmental Laboratory (EL), WES. This report was prepared by Ms. Kelly A. Burks and Dr. Michael F. Passmore of the Environmental Resources Branch, Walla Walla District Corps of Engineers.

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The report was prepared under the general supervision of Mr. H. Wade West, Chief, ECB; Dr. Robert M. Engler, Chief, Natural Resources Division; and Dr. John W. Keeley, Director, EL.

At the time of preparation of this report, Mr. Kyle E. Schilling was Acting Director of WRSC and Dr. Robert W. Whalin was Director of WES. Commander of WES was COL Bruce K. Howard, EN.

Table of Contents

Introduction

Planners in the U.S. Army Corps of Engineers are required to rapidly assess environmental impacts and aid in developing cost-effective solutions during the plan formulation process of project design (USACE 1990; 1995a, b, c). To fully evaluate an alternative design (or management scenario), a planner must gather pertinent data, determine biological outputs, and assess cost-effectiveness. These analyses can be completed using a variety of software packages and support documentation. For example, several automated Habitat Evaluation Procedures (HEP) and Incremental Cost Analysis (ICA) software packages are available to the planning community (National Biological Service 1994; U.S. Fish and Wildlife Service 1986; Robinson et al. 1995) . These methods, although an improvement on past methods, can be time consuming and inefficient when analyzed separately for larger more complex applications. Another type of support software, called geographic information systems (GIS), uses relational databases to electronically link data to points on the earth. These systems have proved invaluable in providing spatial information necessary for the decision-making process. However, many decision-makers have neither the time, nor the inclination, to master the operational complexities of a general-purpose system such as GIS.

In effect, a decision support system is needed that allows planners direct access to the pertinent information (biological outputs, spatial relationships, and associated costs) and software packages that are required to evaluate a design scenario within a single, integrated, computer environment. An Integrated Bio-Economic Planning System (IBEPS) could directly address these needs. The IBEPS would use a relational database to compile results of environmental and economic analyses, tying these results to spatial attributes through the use of GIS, and reporting results in a format understood by the planner and decision-makers.

The potential applications of the IBEPS are numerous. For example, the IBEPS could be used as a tool to support selection of biologically productive and cost-effective solutions for stream restoration projects under the Section 1135 program (Water Resources Development Act 1986, as amended; Public Law 99-962). A planner could quickly assess potential restoration alternatives and provide a cost-effectiveness analysis based on all designs proposed. In addition, the IBEPS could supply a multiple-species assessment of benefits for designs using a single workstation in a relatively short period of time. The planner could then report these analyses by linking the IBEPS's results to a word processing package. The IBEPS could also be used to aid planners in the selection of mitigation sites, by assessing environmental losses caused by the project, and analyzing sites that may satisfy mitigation requirements.

This report describes the conceptual design of a computer-based decision support system that links existing HEP models and ICA software to spatial data through the use of an analysis engine. This will allow users to semi-automatically run HEP and ICA software linked to spatial data. Biological outputs (HEP habitat units) and ICA annualized costs are based on user-provided inputs of expected costs and expected habitat changes.

This project was sponsored in part by the Evaluation of Environmental Investments Research Program (EEIRP) being conducted jointly by the U.S. Army Engineer Waterways Experiment Station (WES) and the U.S. Army Institute for Water Resources (IWR). Partial funding for the development of the IBEPS program was also provided by the Office of Environmental Policy, HQUSACE. This report is published because of its potential use by Corps district personnel for evaluating the effectiveness of environmental restoration and mitigation projects. It does not reflect the design for a decision support system being developed to incorporate all products of the EEIRP.

Goals of the IBEPS Prototype

The primary goal of the IBEPS program will be to evaluate both the cost-effectiveness and biological effectiveness of expected habitat quality changes associated with multiple management designs (within a GIS environment). Therefore, the user of this system (planner, environmental resource specialist, biologist, etc.) has the following critical needs that must be addressed if the IBEPS is to be useful.

a. First, the system must be very easy to operate and the databases/models must be accessible. This criterion rules out software with complicated programming features with lengthy training requirements. This restriction also forces analytical tools employed by the IBEPS to produce results in a language and format familiar to the user.

b. Second, the system must be comprehensive. Sound management decisions are made when <u>all</u> the relevant facts are known. By concurrently addressing the environmental, spatial, and economic factors, the system can provide support for more informed decisions.

c. Third, the system must be logical to planners. Erratic jumps in logic or complexity of functions within the IBEPS environment could result in a planner losing faith in the system's ability to accurately and efficiently support management decisions. The IBEPS should provide a logical sequence of analyses, while maintaining a simplified format.

d. Fourth, the IBEPS program should be adaptable. For example, if conditions merit modifications in biological models, the system must provide a means to implement new models.

e. Fifth, the IBEPS program needs to produce the results of its analysis in a reportable format. As designs are assessed, results must be converted to report formats (e.g., graphs, tables, maps, etc.). Directly linking these software products to the IBEPS will improve efficiency. As the system analyzes and updates its products, it will be capable of simultaneously updating products in the word-processor. Thus, the user can produce updated reports without having to re-enter data.

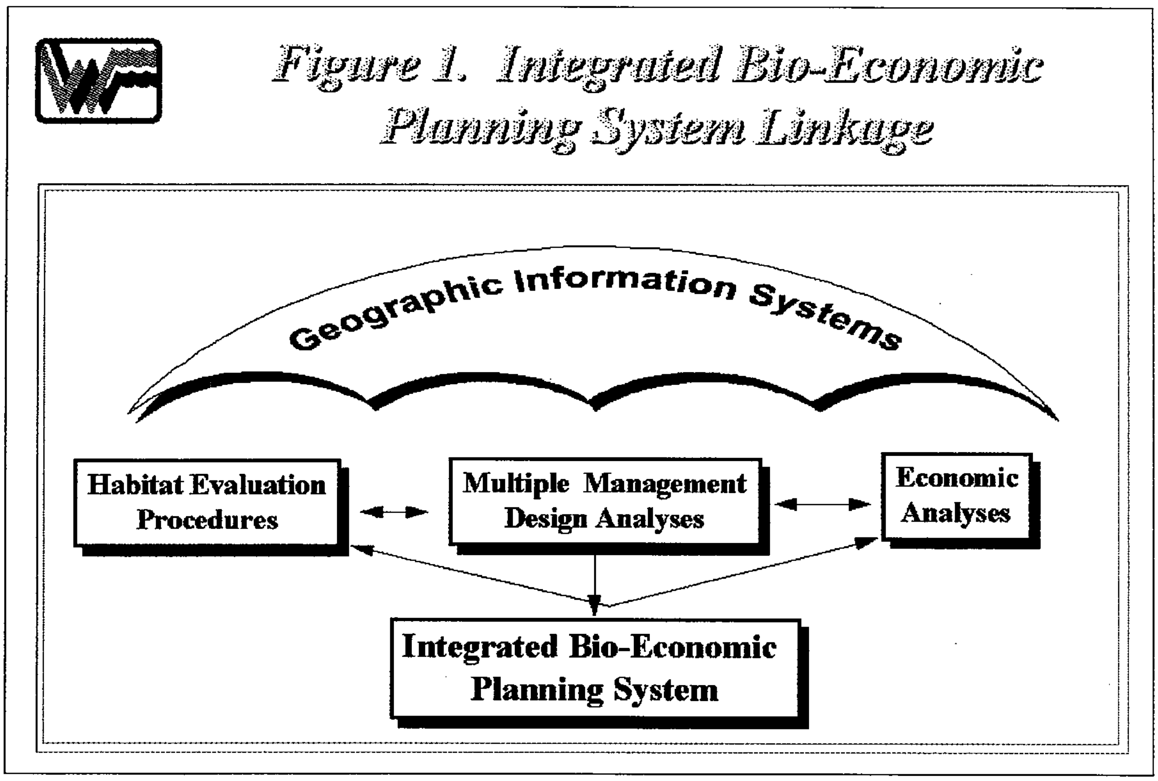
f. Finally, the system should be instantly responsive to the user's design criteria. Changes in the design (such as increases in cover type acreage or decreases in quality

factors within that covertype) must be immediately assessed within the system, and the final report must reflect the new design impacts.

The Integrated Bio-Economic Planning System Components

The conceptual design of the IBEPS program has four major components (Figure 1):

- ♦ Spatial analysis and applications (GIS).
- ♦ Environmental evaluations (habitat evaluations and outputs),
- ♦ Economic analyses (costs),
- ♦ Multiple management design analyses.



Spatial Analysis and Applications

Geographic information systems will be a central feature of the IBEPS prototype. GIS is capable of storing and displaying conventional spatial information in a logical fashion through relational databases and map reproduction. GIS is considered a relational database because it integrates data in a spatial context (that is, it ties features such as roads, lakes, and elevations to specific points on the earth).

For the past several years, the Walla Walla District's Environmental Resources (ER) Branch has developed an extensive GIS database covering the District's region and facilities, using Intergraph's Modular GIS Environment software. The database contains transportation networks, project boundaries, topography, hydrologic parameters, elevations, vegetative classifications, etc. The ER Branch has recently incorporated new technological advances in imaging which will produce vegetative classifications from most media (for example, aerial photographs and digital airborne/satellite images) using Intergraph's Image Station Imager (2) software. Once classified, the quantity (that is, number of acres or hectares) will be linked to the software used in the environmental analysis section of the IBEPS described below. Thus, the GIS database in the Walla Walla District is available for integration of the IBEPS linkage.

Environmental Evaluations

Evaluation of environmental benefits and losses can be performed in a variety of ways. Population sampling, qualitative matrices, life history modeling, and many other methods have been employed with varying degrees of success. Of particular interest in this study is a multi-covertype Habitat Evaluation Procedure Spreadsheet (EXHEP) developed by the ER Branch in 1994.

A traditional HEP can be considered a biological accounting system. The currency or output for HEP is typically expressed in Habitat Units (HUs) or annualized units called Average Annual Habitat Units (AAHUs). An HU is a measure of the quality and quantity of a particular covertype (for example, riparian forest) and is calculated by multiplying the quality by the quantity. Quality is measured as a habitat suitability index from 0.0 to 1.0. The index reflects the measurement of limiting factors for each species, where 0.0 is the lowest quality and 1.0 is the optimum quality. Quantity is typically measured in acres or hectares.

The EXHEP system combines the complicated biological models of multiple species, the quality of the covertypes, and the acreage for each covertype within an EXCEL 5.0 workbook. The EXHEP can be directly linked to the IBEPS. This linkage would allow the user to directly input quality measures for each covertype by species. The IBEPS program could then derive quantity measures (needed in the EXHEP calculations) indirectly using the GIS applications (described above). The environmental output (HUs) would be reported in tabular fashion by IBEPS (Figure 2).

Figure 2. Habitat Evaluation Procedures

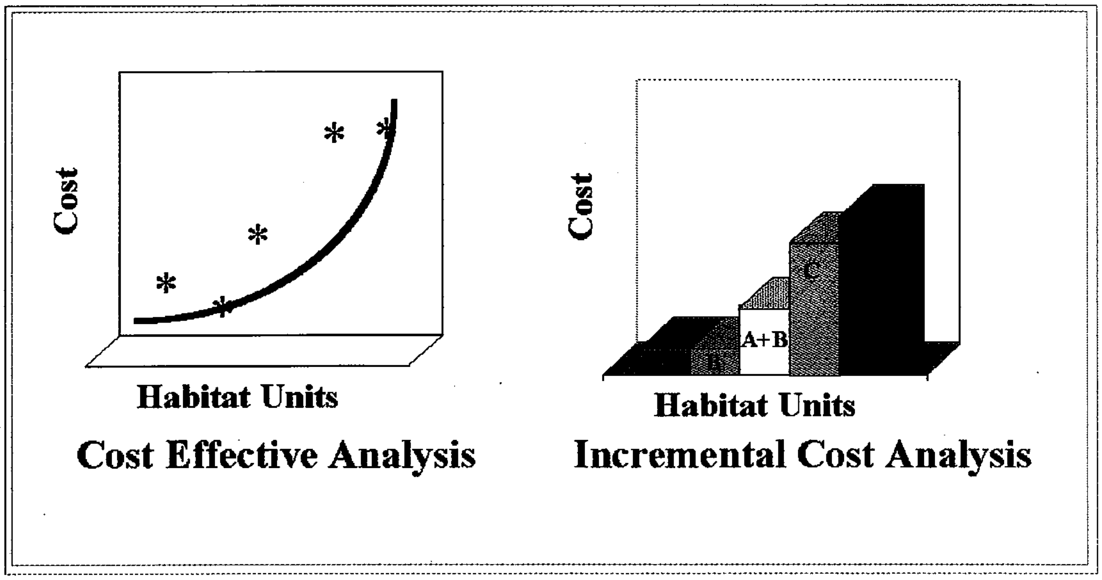
HEP Results (HU's) for the Oxbow Design #A

Evaluation Species	Covertype Utilization	No Action	Management Scenario A	Management Scenario B	Management Scenario C	Management Scenario D	Management Scenario "n"
Downy Woodpecker	Forest	+10	+15	-9	+25	+16	
Song Sparrow	Mesic Shrubs	+0	+0	+15	+25	+25	
Song Sparrow	Forest	+5	+14	-10	+19	+15	
Yellow Warbler	Scrub Scrub	+0	+0	+20	+7	+20	
Marsh Wren	Wetland Emergent	+0	+15	+20	-10	+10	
River Otter	Shoreline	+5	+5	+2	-16	+20	
Western Meadowlark	Grass, Shrubs, Forbs Grass, Shrubs, Forest	+25	-20	+15	+25	+20	
Mule Deer	Scrub Shrub, Forbs	+5	+10	+11	+27	+25	
Chukar	Grass, Shrubs	+5	-15	+10	+15	+20	
California Quail	Crops,Grass, Shrubs, Forest, Scrub Shrub, Forbs	+5	+10	-14	+16	+18	
Mallard	Wetland	+0	+10	+24	-20	+20	

Economic Analyses

The IBEPS program will assess the cost-effectiveness and incremental effectiveness for each proposed design by linking (via EXICA, an EXCEL 5.0 interface developed in collaboration with WES and IWR) to an economic analysis software package (CEA2) developed by WES and IWR. Once the designs are created and the environmental analyses are completed for each design, the planner will enter project costs into a table that acts as an interface for EXICA. EXICA will conduct a cost-effectiveness analysis (that is, analyzing output per unit cost) and will produce cost-effectiveness curves that can be directly imported into any report (Figure 3). EXICA will also conduct an incremental cost analysis that will reveal changes in incremental costs for increasing levels of environmental outputs (HUs), which will be displayed in a bar chart format for reporting requirements (Figure 3).

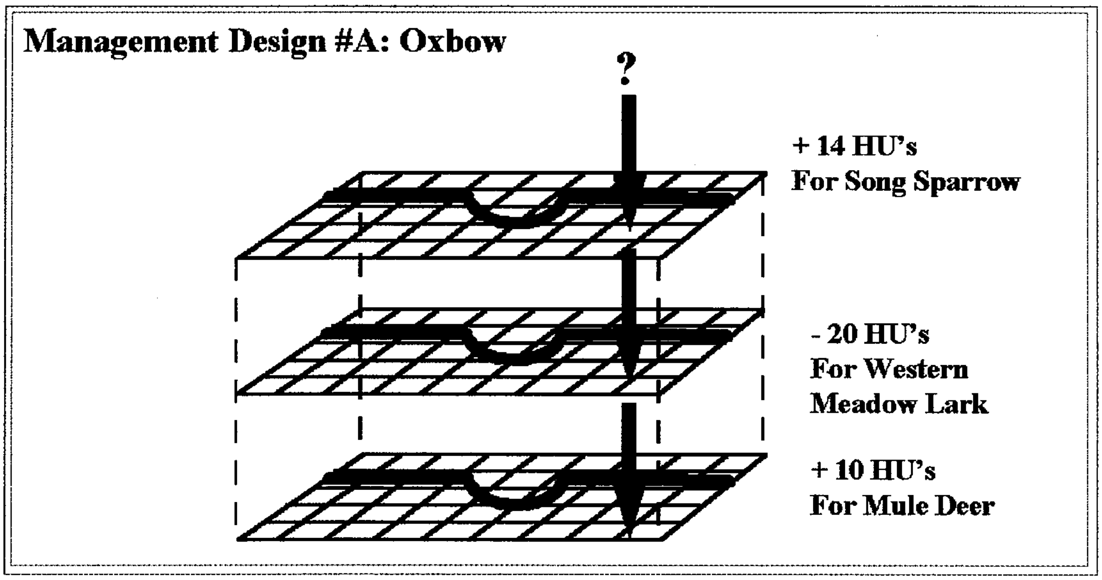
Figure 3. EXICA Products



Multiple Management Design Analyses

The Multiple Management Design Analyzer (MMDA) will be the planner's link to the IBEPS's components (GIS, EXHEP, and EXICA). The MMDA will be a single screen through which the planner can design multiple management scenarios <u>and</u> assess their impacts simply and easily. The planner will evaluate baseline inventories (satellite images, color photos, video graphical information combined with EXICA and EXHEP results). In the same screen, the planner will be able to draw hypothetical management designs on the screen. In addition, the planner will provide input (for example, costs and quality data) in the MMDA screen. The IBEPS program will appraise multiple species outputs for each management design and report these to the user via the MMDA screen. Once the planner completes the designs, the IBEPS will assess cost-effectiveness and incremental effectiveness for the multiple scenarios and multiple species. The system will proceed to evaluate biological production in a three-dimensional matrix (with species, acres and quality as axes) (Figure 4), thereby allowing the assessment of multiple species and multiple scenarios simultaneously. IBEPS will then report the biological outputs (benefits or losses) for each species per design scenario and assess these on the basis of economic cost-effectiveness. These reports will then be produced for the planner.

Figure 4. 3 - Dimensional Matrix



IBEPS Linkages and Sibling Systems

A handful of software packages (sibling systems) will link the necessary components together under the IBEPS program. The primary interface between the user and the IBEPS is very important. The Visual Basic 4.0 Screen (referred to above as the MMDA screen) is recommended. Three sections are displayed on this screen.

- ♦ The first section displays a "paintbrush" image of the site. To create this image automatically, data must be rasterized, imported, and converted to a simple paintbrush format using a grid analysis program. The planner will then be able to design projects inside the image on the screen. This section will also allow a planner to review the actual satellite images (or aerial photos) of the site.

- ♦ The second section in the MMDA screen displays an EXHEP table. Here, the planner will enter the EXHEP program and review baseline conditions for multiple species. The planner can then manipulate baseline conditions to reflect project implementation, and can change the quality of covertypes for multiple species to achieve project objectives.

- ♦ The third section in the MMDA screen contains the EXICA interface table. Here, the planner will run the EXICA program using a pull down menu command in a spreadsheet program. Cost analyses will then be performed on the proposed design alternatives.

How Will the IBEPS Work?

Step one in the IBEPS process will be to gather and review the baseline data. The following information will be required to assess baseline conditions and configure the EXHEP database:

- Initial vegetative classifications and quantities are very important. This information must be entered into the GIS and exported to the IBEPS system for input into EXHEP. For example, a satellite image could be scanned into the GIS, and the Image Station Imager could be used to classify vegetative covertypes and acreage per covertype. The scanned image would then be exported to the MMDA screen (described above). It should be noted that importation of information will be a uni-directional process (that is, information can only move from the GIS database out to the IBEPS). This uni-directional criterion ensures GIS database integrity. Once exported, the selection and classification of covertypes will be used in conjunction with the selection of species models described below to assess baseline conditions.

- Selection of species and associated HEP models will need to be entered into the IBEPS as well. The selection and modeling should reflect species impacted (both positively or negatively) due to project design. The selected species do not need to be mutually exclusive (that is, species that use completely different covertypes could be considered mutually exclusive). Outputs from species-specific HEP models should not be summed except under special conditions.

- The "without-project" condition must be determined. Impacts or improvements must be measured against the baseline ("without-project") condition; thus IBEPS requires this information prior to assessment.

Step two in the IBEPS process will be the design of management measures inside the MMDA screen. A planner could re-assign an existing covertype polygon to a new classification (described above). A planner could also choose to design new covertype polygons. Once the designs are completed, costs must be determined.

Step three will involve querying the system. The planner will be able to view biological outputs and covertype quantities for each design by accessing the EXHEP via the MMDA screen. Cost-effectiveness and incremental effectiveness will be examined in tabular or graphical form by accessing EXICA. Finally, impacts on multiple species will be compared for each design quickly and simply via the MMDA screen.

Step four will be the selection of an environmental restoration or preferred mitigation design and reporting of the analyses in an easily understood format. Graphics and tables produced inside the IBEPS program can be imported into word processing documents. These graphics and tables will be linked directly to the spreadsheet packages, and therefore will be updated automatically as the data inside the IBEPS changes.

Conclusions

Corps of Engineers planners need to rapidly assess the overall effectiveness of alternative designs for proposed environmental restoration and mitigation projects during the planning process. Currently, the volumes of information necessary to make environmentally sound decisions are scattered among a variety of software packages and reference materials. Furthermore, the information lacks the spatial linkage necessary to easily define the critical impacts of environmental management designs. The IBEPS program will integrate biological, spatial, and economic factors into a visual medium that will allow planners to design and compare management scenarios quickly and easily. The IBEPS will operate from a single workstation, making it unnecessary to be linked directly to a GIS database at all times. Flexibility will be a major advantage of the IBEPS program. Substitution of software packages (spreadsheet substitutions such as Quatro Pro or Lotus 123 for EXCEL 5.0) can be accommodated relatively easily. In addition, substitution of baseline materials, biological models, and GIS visuals can also be incorporated into the program.

It is the intent of the Walla Walla District to complete development and test the IBEPS prototype with an environmental restoration project during Fiscal Year 1996. Questions concerning the IBEPS should be directed to Ms. Kelly A. Burks at (509) 527-7266.

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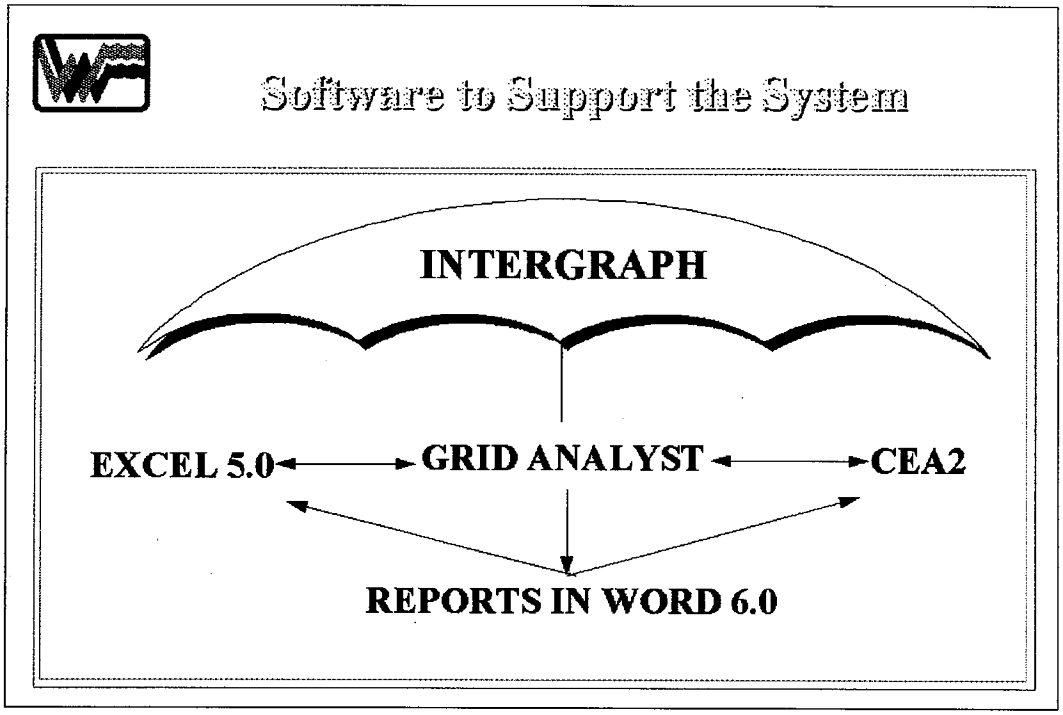
Appendix A: Proposed Software

Appendix A

Proposed Software (Figure 5)



Spreadsheets and models
- EXCEL 5.0
- EXHEP (requires EXCEL 5.0)
- EXICA (requires EXCEL 5.0 and CEA2)

GIS
- Intergraph Modular GIS Environment (MGE)
- IRASC

Graphics
- Paintshop Pro

Interface between software listed:
- Visual Basic 4.0

Word Processor
- Word 6.0