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Report on the Decision Support Systems Workshop

Denver, Colorado
February 18–20, 1998

Open-File Report 99-351
1999

U.S. Department of the Interior
U.S. Geological Survey

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Gene Lessard and Thomas Gunther, Editors

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PREFACE

The Interagency Group on Decision Support

Thomas Gunther

The Interagency Group on Decision Support (IGDS) was formed in 1997 to provide more communication and cooperation among developers and users of decision support tools and services aimed at land, natural resource, and environmental management. Participants from multiple agencies and the academic and private sectors have held a series of meetings to share knowledge of existing decision support systems and applications, and to discuss unmet needs and opportunities. Tentative conclusions from these meetings include: 1) powerful tools and systems are available or under development; 2) while individual tools or systems may incorporate one or more excellent features, no one system provides or is likely to provide the broad range of capabilities needed by all decision makers and stakeholders; 3) while some aspects of decision support are very sophisticated, others are still in their infancy; 4) no one agency or developer is likely to have the budgetary resources or mission to develop and maintain the range of tools needed by decision makers; and 5) current and evolving technology, fixed or shrinking budgets, and increasingly complex challenges of resource management combine to provide an opportunity for expanded cooperation in the development of the next generation of decision support.

The IGDS developed a draft charter (see Appendix) including a statement of its purpose and objectives, and began discussing possible actions that could accelerate or facilitate the development of decision support tools and systems. One of the first actions adopted was a plan for a workshop that would provide exposure to the broad range of existing tools and systems, and generate a common basis for future discussions and an appreciation for the state of the art. A list of tools and characteristics believed important for decision support was initiated, participants were asked to identify systems or tools that could be displayed at the workshop, and a site and date were selected. This report on the proceedings of the workshop captures presented papers and case studies relative to decision making and decision support and abstracts of the systems and **tools** demonstrated at the meeting.

It is hoped that future meetings, hosted by various organizations, will build on the results of this first workshop, and provide continuing opportunities for collaboration among developers and users. Participation in the IGDS or its workshops is open, subject to rules, regulations, and resource limitations.

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INTRODUCTION

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This publication reports on the workshop on Decision Support held in Denver, in February 1998. It was organized and conducted by the Interagency Group on Decision Support for Land, Natural Resources and the Environment (IGDS), a self-directed team whose goal is to facilitate the development of Decision Support Systems among numerous federal agencies, to minimize the costs of development, and to ensure systems are developed that are useful to agency decision makers. The workshop had a number of purposes:

To discuss the basic principles of decision making from a decision science perspective;
To review an array of decision support tools to inform agency staff of the types, functions and uses of a number of different decision support systems;
To bring developers together in an informal forum to learn about current decision support systems, analysis tools, and their uses;
To construct a decision science framework from which to develop a decision support systems framework and analytic tools; and
To begin formulating the role of the IGDS.

To initiate and stimulate discussion, a working definition of a decision support system, and a list of characteristics and tools was developed and presented. Workshop participants defined a decision support system as "an interactive, computer-based tool or collection of tools that uses information and models to improve both the process and outcomes of decision making." Ideally, participants recommended, a DSS should have the following:

Characteristics:
Readily accessible and affordable hardware and software;
Intuitive and adaptable user interfaces (including adaptability to different levels of user sophistication);
Modularity to allow incremental development and "Lego" like construction of systems;
Internet connectivity and ability to use distributed databases and models;
Interoperability to allow use of components regardless of where they are developed; and
Logging and tracking to document decision processes and facilitate records of decision.

Tools:
Geographic Information Systems capabilities;
Ability to accept and utilize real-time data;
Ability to select different geographic and temporal scales;
Modeling and simulation tools;
Visualization tools to display data, relationships, and anticipated results;

Mechanisms to allow structured stakeholder involvement;
Tools to facilitate adaptive management and monitoring;
Means to depict uncertainty in data, relationships, or results;
Explicit methods to treat multiple goals, objectives, and measures; and
Ability to create and store scenarios.

No existing DSS incorporates all of these features but, using them as a starting point, the IGDS invited a number of developers and agency technical staff to participate in this workshop. A variety of views, case studies, and technical presentations resulted, and are reported in this document. A brief summary of presented papers is also provided below.

John Kelmelis: According to Kelmelis, the current approach to decision support requires highly trained technical experts to operate systems for the decision maker. The future system, or virtual decision support system, will interface directly with the decision maker. This virtual system will provide greater access to more data and analytical models. Systems will be built directly by communities or organizations in real time to solve real problems. Systems will also provide monitoring capability for adaptive management. Although the technical environment is changing rapidly, the elements of the decision environment are likely to remain constant.

Dave Cleaves: Cleaves presented five functional components (phases) of decision making:

Process Mapping: deciding how and who will decide;
Problem Framing: describing the problem to be solved (or opportunity to be captured);
Intelligence Gathering: collecting and integrating information;
Evaluating and Choosing Alternatives: comparing alternative courses of action; and
Learning from Feedback: collecting and processing feedback information.

Cleaves developed "criteria for judging decision quality of individual phases," and "criteria for overall process integration." He noted that several dynamic trends are assuring changes in the context for decision making that have implications for decision quality: These trends include:

Agency downsizing;
Pervasiveness and domination of political uncertainties;
Emphasis on measurement of performance;
Proliferation of procedural regulations and decision processes;
Loss of site-specific expertise;
Breakdown of functional dynasties;
Fewer decision makers with expertise in managing distributed decision processes; and
Shift in conflicts.

Cleaves also developed a list of potential applications for each of the five functional components (phases) of decision making.

Todd Mowrer: Mowrer maintained that addressing the changing environment for decision making requires significant organizational changes in government. However, change doesn't come easily. To operate in this technologically, socially, and politically sophisticated arena during an era of rapid change, we must:

Facilitate seamless management across administrative and ecological boundaries;
Promote uniform and more defensible decisions; and
Expedite analytical processes where essential skills are in increasingly short supply.

Deena Larson: Agencies are developing new frameworks for decision making. Two were discussed at the workshop and are presented in this report. The first is the Bureau of Reclamation's "Decision Process Program." Based on extensive interviews, the Bureau developed a guidebook (and a hypertext version at <http://www.usbr.gov/Decision-Process>) on "how to solve problems through reasonable, sensible, and responsible actions." The Program has several options for training:

General Overviews: participants work through a simple decision process to understand and apply decision steps and concepts.
Applications: trained facilitators lead groups through a process.
Guide the Guides: in -depth training for facilitators.

Larsen also describes an adaptive approach to problem-solving, tailoring the decision makers' needs to a decision process. The decision process is a ten step framework that shows what information is available, relevant, and needed. The process steps are:

Needs Assessment
Objective Setting
Resources & Constraints
Range of Options
Screening Criteria
Alternative Development
Evaluation - Rank Alternatives
Selection Alternative
Implementation
Follow up

Deborah Shields, *et al:* The second new agency framework was discussed by Shields and her colleagues, who focused on the results of research into Measuring Stakeholder Preferences. They developed a framework for land management that views the interaction between societal values and land use decisions in a hierarchical manner: basic held values determine social objectives that, in turn, drive management decisions. In this hierarchy, basic values are assumed to provide the motivation for determining land management goals and objectives, which, in turn, affect attitude formation and consequent behavior.

A survey instrument was developed to quantify information about values-goals-attitudes-behaviors with respect to public lands. This quantifiable information could be used to inform planning at scales ranging from national to local. Finally, Shields *et al* noted that the framework facilitates stakeholder involvement in agency planning and fits well within the current sustainable forest management paradigm.

Brand Niemann: Niemann provided an overview of some practical decision support systems tools and offered a start for some next steps in data mining, advanced exploratory data analysis, and visualization tools.

In addition to the presented papers, three case studies using innovative approaches to support analysis and decision making were examined: the Famine Early Warning System, the Ground Water Modeling System, and the Southern Appalachian Assessment Geographic Information System. Finally, 25 demonstrations were conducted throughout the week. Abstracts of each demonstration are included in this report.

PRESENTED PAPERS

The Changing Decision Environment

John Kelmelis

I. Introduction

Imagine a future where people in all walks of life and all levels of government have access to sophisticated tools to help them make land management decisions. Imagine a future public meeting in an average county. County officials, land owners, and citizen groups are assembled to discuss a proposed land development project. Using the Internet, the group is able to access much of the needed data to combine with information it has acquired itself. Using the Internet, they are also able to access the numerical simulation models needed to conduct their analysis, and the visualization software required to display the results. A search engine on the Internet is also able to find computer capacity elsewhere that is sufficient to run simulations in real or near real time.

Projected on the screen at the front of the assembly or as a holographic image in the center of the room with people gathered around is a resource map of the region upon which a technician is busily integrating information on hydrology, soils, roads, existing land use, vegetative cover, a planned development, and other variables at the request of the meeting participants. The technician highlights a river, incorporates proposed levees on the bank, and zooms in to reveal the existing land use patterns, land cover, soil types, and surficial geology. Next, computer model simulations are run depicting potential flood scenarios and the effects of different development options. As the discussion proceeds, the technician modifies maps of the region to account for suggested changes. A consensus begins to emerge on a land use plan that both is acceptable to the local land owners and provides an adequate floodway, while clearly displaying the risks of the various alternatives to all involved.

In short, the community has built and used a decision support system (DSS) on the fly.

Elsewhere in the county, a farmer is examining maps of his property generated minutes before from a personal computer linked to the Internet. He combines information about soil characteristics, past and forecasted weather information, recent market projections of future crop prices, optimal fertilization practices for different crops, and precision pesticide use for the various crops to produce a series of maps that will help guide decisions about the upcoming growing season. These include maps depicting the optimal tillage, planting, fertilization, pesticide application, irrigation, and harvesting plan to identify the most cost-effective strategy for the coming growing season. This is true precision farming.

Hundreds of miles away, Federal analysts are reviewing several policy options that would allow farmers to convert wetlands to croplands. The options, generated by Congress, are being evaluated using geographic information systems (GIS) and sophisticated economic and land use models to provide the information required to make a decision on competing policy goals. The analyses demonstrate the effect of each policy option on the change in agricultural productivity on a crop by crop basis, the loss of wetlands, the aggregate effect of that wetland loss on water quality and flood flows, and the potential changes in both productivity and potential environmental degradation based on the introduction of agricultural chemicals into the environment. These are evaluated in light of pricing changes for crop commodities.

What do these vastly differing scenarios have in common? What makes them different from what we can do with sophisticated DSS's today? The answers to these questions are straightforward.

First, they represent real world problems of the type we address today. Second, many of the technologies useful to make decisions with respect to those problems exist now in one form or another. However, to address the applications in the way described would take major modifications to some of these technologies, might require the invention of new capabilities, and would require a modification in the way we use many of them. Third, each of the examples presupposes an ability to communicate with the technological environment and DSS at a high enough level so that highly trained system experts would not be needed during implementation. Fourth, the systems improve the communication among humans; after all, people ultimately make the decisions, not the computers. Fifth, the DSS provides useful and readily understandable information about the consequences of different decisions.

The present approach to these types of analyses is to use stand alone systems, often with unique data sets, process models built for the specific problem, and a user interface that limits access to highly trained technicians. The DSS's described at the beginning of this paper are different from our sophisticated DSS's of today in that they are accessible to a wide segment of the population, thus democratizing information and improving opportunities for participatory decision making. They are also constructed from a vast resource of interoperable models, data, and other tools that can be linked rapidly and efficiently to address unique problems. The DSS of the future will exist in a different technological environment, but the decision environment will probably be very much as it is today. This paper discusses the changing technological environment and the existing decision environment. It also suggests what technological advances would be necessary to make the vision of widely operable, efficient DSS's a practical reality.

II. Changing Vision for Decision Support Systems

The current standard approach to DSS's consists of highly trained technical experts operating the system for the decision maker. In this approach there is a user interface that manages dialogue between the human and the data base management system (DBMS) and model base management system (MBMS). The MBMS interfaces with the model base located in the system's memory and the DBMS interfaces with the data base located in the system's memory. The DSS's are run in the computer using the models and data that have been stored locally or on other computers owned by or operated for the enterprise.

The virtual DSS is a vastly different approach. In it there is a user interface that contacts an intelligent DSS building tool (DSSBT). The user describes the problem. The DSSBT uses an expert system to help the user locate the appropriate process and constraint models resident on file servers at various places on the Internet. The DSSBT reads the metadata about the models to determine if they are appropriate to the task. (Metadata are data about the content, quality, condition, and other characteristics of the data.) These metadata are data about the model, the domain in which it is appropriate, its operating parameters, the data it needs to operate, and other characteristics of the model. The DSSBT, either independently or interactively, accesses those models and builds the system of these integratable models. Thus, the models are modules (located anywhere accessible on the Internet) that can be retrieved and assembled into larger systems.

Based on the requirements the model identifies, the DSSBT mines data bases resident on the same or other file servers linked to the Internet. In this case, the DSSBT reads the metadata about the data to determine if they meet the requirements of the models and the specific problem. If the hardware available to the user is not sufficient to store and operate the system that is being built "on the fly," the DSSBT searches for a computer or computers with sufficient capacity to run the DSS. The result is a virtual decision support system. The user is kept informed throughout the process and can intervene at any time to provide direction. The results of the analyses are displayed in the manner selected by the user. Possible future scenarios resulting from the "what if" analyses conducted by the DSS are displayed with an easily understandable measure of the uncertainty of the outcome. Because someone may wish to rerun the DSS in the future, a log of all models and data used is maintained, along with versions, access information, running sequences, and other pertinent information.

The virtual DSS approach has distinct advantages over enterprise systems. Some of these are greater access to more data, analytical models, and other decision support tools. Such systems may be built by communities or organizations that do not have the capital to invest in individually built specialized enterprise DSS's of their own. There are disadvantages as well. These include the potential for misuse, the potential for misunderstanding the analysis by people who do not have the appropriate training, and the potentially high cost of standardization necessary to ensure that the systems are interactive. However, the economic savings to society through reducing the development of redundant models and data may offset those costs.

The capability to monitor the results of any decision that is made can be included if adaptive management approaches are being used. The result is the provision of more information to the decision maker in a form that actually helps the decision process because of its timeliness, appropriateness, and understandability.

Although this future DSS capability may seem somewhat unrealizable and fraught with insurmountable obstacles, the advances that have taken place in technologies over the past thirty years suggest otherwise.

III. The Changing Technological Environment

There is no question that technologies of all types have been advancing rapidly. Technologies that underlie the information infrastructure are no exception. A few of the recent technological advances that have led to the possibility of the vision described above are listed in Table 1 (included at the conclusion of this paper). In order to understand how rapidly those advances are being made, consider where we were thirty years ago and where we are today with some common communications technologies.

A. **Where we were**: Thirty years ago, in 1968, there was only one long distance telephone company. The average household owned no telephones. They were all rented from "Ma Bell." These phones had only one function and had no phone mail or call waiting. Portable phones and car phones were rare and required bulky radio communications transmitters and receivers. Cellular phones did not exist. Homes did not have cable television or personal computers in them. The personal computer industry was effectively launched by IBM in 1981, although desktop models of computers were introduced in the late 1970s. Depending on whose definition you use, there were four civil geographic information systems in 1968. There was no commercial use of satellite imagery and digital decision support systems (DSS) were in their infancy. They were used principally in the manufacturing business.

B. **Where we are**: Thirty years later we find ourselves with numerous long distance telephone companies. Personal telephones are ubiquitous, often portable, and no longer limited to a single function. We own them, too. They are connected both by land lines and by radio transmission. Televisions are ubiquitous, receiving information from signals broadcast by ground-based antennae or satellites, as well as by wide band cables. There is also common home use of personal computers, a technology for which many industry experts felt thirty years ago that there was and would be no home market. Internet use is widespread and growing geometrically, ensuring that communications of information of all sorts is available to the home user. In addition, there is common professional use of geographic information systems, airborne and satellite remote sensing, satellite geopositioning, digital computerized process models, satellite telecommunications, and DSS's.

C. **Where we are going**: The use of technology for decision support will increase as more capabilities become available and the need to better manage our resources becomes more apparent. We live in a world of increasing demand driven by population growth, the desire for improved standard of living, and the realization that many decisions in the past have resulted in unintended negative consequences that must be corrected. Because the resources are location dependent, there will be increased use of spatial technologies such as digital mapping, remote sensing, geographic information systems, and spatially based process models. Because it will be impractical for one organization to produce and maintain the wide variety of data and models needed to inform many of its decisions, there will be an increased use of telecommunications technologies, resulting in increased sharing of data, information, analytical tools, and display tools. There will be an increase in sharing of capabilities (hardware, software, and human intellect) and capacity (computer, communications, and otherwise). Virtual DSS's described above can grow out of these capabilities.

D. **Where we could be:** The assumption that supports the input of capital and energy to develop this widely accessible decision support capability is that the availability of relevant, timely, and understandable information will lead to better decisions. *This is not a given.* There is current research focusing on understandable information and whether all of this technology produces better decisions. In addition, experience has shown that decision support systems will be built for specific purposes, as will data and models. If they are incompatible and cannot be integrated, linked or otherwise used for multiple purposes, there will be a large and unnecessary cost incurred by duplication of effort. Information technology is already becoming more compatible and interoperable. For instance, documents can be traded among various word processing programs, programs compiled in different computer languages can be linked, and geographic information technology is moving towards an open system architecture.

E. **What we need to get there**: Although current technologies can be assembled to meet the goal of a virtual DSS, the resulting system would be clumsy, difficult to use, and somewhat unreliable. It would have a very limited set of applications and much new data would be necessary for many of the applications. A number of important advances in technology, data and data management, communication of information, understanding of how different components of the environment interact, and education of the general populace would be needed to ensure an efficient and effective environment for building usable virtual DSS's. These include:

1) Technology

User interface: Numerous types and styles of computer program interfaces already exist. Many are becoming easier to use as we make them more intuitive or as we develop an experience base and understanding of the new language of user interfaces. Regardless, considerable progress can be made in simplifying the user interfaces of all forms of decision support tools. This includes improving the intuitive nature of the interfaces by making them compatible with one another, developing their ability to understand natural language commands, and making them more accessible to a broader segment of the population than the trained technical expert. The long range view indicates that the use of these types of tools and the interfaces needed for them must become part of the educational process.

Intelligent DSS building tools: Existing tools for building decision support systems construct them at the user's request from a known model base and a known data base. Their primary function is to build the links among the models. To make the vision of virtual decision support capabilities built on the fly with ready and easy access a reality, more advanced DSS building tools (DSSBT) will be necessary. They include the ability to use the input from improved user interfaces to search cyberspace for models, data, computer capacity, and visualization modules. The DSSBT will also need the ability to independently or interactively assemble the components into a system that can provide usable output to the decision making process.

High level open system architecture: To make all of this fit together, a commonly accepted architecture must be available. This architecture must consist of interoperable protocols that allow a wide variety of tools, data, operating systems, and hardware to be connected to produce results. It will have to be flexible enough to accept different types of modules and data and translate them into compatible structures, formats, and languages from a finite set of existing standards. The result will be an open system architecture that promotes interoperability.

Computer capacity: Some models or data sets will be quite complex and their analysis will require more computing power or capacity than is available locally. An efficient method of finding and sharing additional capacity and computing power will be necessary.

Effective and secure on-line payment methods: Not all data, models, or computer capacity are or will be in the public domain. Cost-effective and -efficient methods must be developed to transfer funds securely among organizations and individuals for use of privately held information and information analysis resources.

2) Data and data management

Available and compatible data: Although data of the appropriate types, accuracies and precision already exist to solve many common problems, insufficient data or data for which levels of accuracy or precision have not been determined will continue to pose impediments to informed decision making. In addition, the set of problems requiring solution will change as the natural and cultural environments change. Existing data must be maintained and updated as necessary in compatible forms. However, new data are needed as well. It is important that whatever data exist that can be used to solve problems be converted to interoperable structures and formats and that any new data produced meet standards for interoperability as well as quality and content. The data must include robust metadata so the DSSBT described above can effectively mine the data bases and independent data sets to use existing data wherever possible.

3) Scientific understanding

Understanding how the Earth system works: Although considerable knowledge of different components of the Earth system already exists, much additional knowledge is needed. Historical approaches to studying the Earth have generally been reductionist. These approaches have served us well by gathering considerable knowledge of processes. Reductionist research is necessary but insufficient. Efforts must be made to conduct integrated analysis using biophysical and socioeconomic sciences to provide the holistic view needed to better understand and model the effects of human actions and natural forcing functions on the Earth system at all scales.

Available and compatible models: Many models are constructed for scientific, economic, management or other purposes. Many of them are single use models but could be used for other purposes or as part of systems if they were compatible with a high level architecture or met some interoperability standard. In addition, there must be metadata for the models that can be mined and analyzed to help select the appropriate models needed to solve the particular problem at hand.

4) Communicating information

A method to evaluate and communicate uncertainty: Although managers are used to dealing with uncertainty, reducing and/or adequately communicating the uncertainty will help them better understand the possible ramifications of their actions. Improved methods of analyzing, communicating, and interpreting the uncertainty must be developed.

Wideband information transmission capabilities: Accessing models and data on the Internet, conducting analyses on remote computers, and receiving results in near real time will require considerably more bandwidth than is currently available. In addition, nodes and hubs must also have vastly increased capacities. Redundancy will be necessary, particularly for applications related to disasters. All available bandwidth, be it land-line, line-of-sight microwave transmission, broadcast, or satellite must be used as appropriate.

Visualization: Displaying information in a way that is easily understood by the general public while providing sufficient information for the practitioner or other specialized user can be problematic. This argues for a variety of presentation types and information representations. All media, new and extant, should be used to ensure the best available communication of the information. In addition to such new visualization approaches as holographic images and three dimensional dynamic maps with pop-up displays, more traditional methods of visualizing information must be used including graphs, charts, maps, tables, text, etc. Special emphasis must be given to ensuring that visualizations are intuitively understandable, scale issues can be adequately addressed, appropriate methods to generalize information are developed, and intuitively understandable methods of displaying uncertainty are provided.

5) Education

Creating the right knowledge base in the population: The World Wide Web has clearly demonstrated that information will become increasingly available to the general population. If the changes described above take place, the general population will have unprecedented amounts of information and analytical capabilities available. To make wise use of this information, the educational system must expand its capabilities to teach the natural and human sciences and give students at all levels the opportunity to learn to use scientific information in a decision making context.

Some of these capabilities may advance because of demand — that is, they may be pulled along by market and popular forces. For example, companies marketing goods and services develop new functions in order to meet consumer demands and compete for their market niche. These developments are the result of a "pull" by the market and result in overall improvements in the products.

Others may need policy direction to be started or even to become established — that is, they need to be "pushed." For instance, in 1994 the President of the United States issued Executive Order 12906, requiring all Federal agencies producing digital spatial data to comply with standards for metadata and data transfer. This has resulted in overall improved access and usability of Federally produced data. A strategy of both pushing and pulling technologies ensures that progress is made in all areas needed to ensure an economic, efficient, and accessible decision making environment.

It should be noted that although the number of bulleted factors is greatest under "technologies," that indicates only the relative ease of identifying some of the components in that category, not that less emphasis should be placed on data and data management, communication of information, understanding how different components of the system interact, or education.

IV. The Decision Environment

Decisions take place in an environment made up of social, economic, natural, and technological factors. Although the technology may change, much of the decision environment will be the same as it is today except that:

more people will have access to the data and analysis resources; therefore,
decisions will be questioned by an increasingly knowledgeable public; which in turn will mean
the outcomes of decisions will be continually tested against evolving knowledge about the environment and a changing set of social values.

Decision support capabilities (DSC) can help in any or all phases of the decision process: in recognizing and stating the problem; identifying goals and objectives; formulating questions; generating and evaluating alternative choices; selecting and implementing alternative choices; or monitoring and comparing results of decisions with the objectives. Understanding the decision environment is as important to effective decision support as are the DSC's and the DSS's that are built from them.

Although many components of DSS's are made in a relatively controlled environment and designed for a narrow set of applications, the decision environment is considerably different. It is heterogeneous, complex, dynamic, unstructured, incompletely understood, and constrained by biophysical and socioeconomic reality (Kelmelis and Gunther, 1998). Ensuring that the decision environment is adequately represented in the design process requires close coordination with the decision maker. As Morton (1971) concluded, "the MDS [management decision system] area cannot be left to computer or other staff personnel. It must involve line managers [end users, decision makers] as active members of the team." In addition, the recent trend of resource management decisions being challenged and resolved through the legal and judicial systems suggests that all parties affected by the decisions — the stakeholders — be represented in the design of the DSS along with the subject matter experts.

Decision environments are vastly complex because they are simultaneously:

A. Heterogeneous: The social forces include values held by society in common and the homogeneous and inhomogeneous mix of values and personal needs and desires of the individuals affected by the decision and/or with an interest in the decision. Similarly, the landscapes upon which decisions must be made often vary within a cartographic or geographic theme. For example, land cover could include range land, forest, and agriculture within the same decision boundaries or a variety of soil types could exist locally, each with a different response to the proposed activity. Similar amounts of variation could take place in other themes such as: land use, ecosystem type, physiographic region, biome, watershed, etc. Moreover, when themes must be overlain during the decision process, implications of the heterogeneity of the environment becomes even more apparent. In addition, the social forces affecting the decision itself are heterogeneous, each maintaining a greater or lesser influence on the decision, its implementation, and the ultimate outcome.

B. Complex: Relationships among the biological, physical, social, and economic components of the environment can be simple and straightforward. However, it is more likely that they will be a complex array of bilateral and multilateral relationships, both tightly and loosely coupled and often interdependent. For instance, climate and vegetation are usually tightly coupled. Land management practices may be tightly coupled. Recreational activities may be tightly or loosely coupled. Vegetation and soil are often tightly coupled, but agriculture may be loosely coupled to soil in some areas with fertilizers, pesticides, irrigation, land surface modification, transportation network, and mechanized farming techniques playing a greater role. In other areas this might not be the case.

Similarly, cultural factors can add complexity to the environment with complementary and conflicting values and real and perceived costs and benefits varying among the stakeholders.

C. Dynamic: The biophysical environment is continually changing in response to both natural and human influences. The decisions we make may influence the future state of the environment in both intended and unintended ways. Some examples are new land uses or structural approaches to environmental controls, increases or decreases of materials released into the environment, evolution or devolution of ecosystems, natural or anthropogenic global change, changes in absolute or relative abundance of natural resources, and introduction of exotic species. Likewise, socioeconomic conditions change: social values placed on various environmental elements shift; demand for commodities grows or declines; political power shifts with changes in demographics of a population; and perceptions of inequities in resource allocation affect social stability. A more subtle, though at least as important, variable is improved knowledge of the biophysical and socioeconomic environments that can greatly alter people's perception or understanding of the appropriate decision or outcome.

D. Unstructured: Whereas structured problems follow a known procedure and have well-defined policies for their execution, many problems, resource and environmental for example, are often poorly formulated based in part on the complexity of existing land use and competing alternatives. There is frequently limited or no prior experience with that type of problem or response. The problem space is poorly defined and often not mature. In these situations, creative thinking and unique approaches to problem solving are necessary. DSS may be particularly valuable but may be difficult to assemble and must be amenable to using a "what if" approach to problem-solving.

E. Incompletely understood: In most cases it is impossible to know the numerous variables in the socioeconomic and biophysical environment that can impinge on many problems requiring management or policy decisions. Similarly, it is impossible to know all of their relationships, and all potential outcomes of decisions they affect. In addition, the processes affecting those variables and relationships are often incompletely understood. Therefore, there can be considerable uncertainty in defining the problem, formulating a rational approach to finding a solution, preparing an acceptable decision, implementing the decision, and monitoring its effects. Thus, decisions that are made can be considered experiments and the results of those decisions as outcomes of the experiment, providing new information to help understand the processes better and improve the outcomes of future decisions.

F. Biophysically constrained: While the implications are not fully understood in all cases, the laws of physics govern the response of the environment to the decisions that are made. Thus, there may be unintended biological, physical, or chemical responses to the decisions if insufficient thought is given to the decision. Although uncertainty may be reduced by analysis and planning prior to the decision, it cannot be eliminated completely because the physical laws are incompletely understood. Moreover, the interactions of complex physical, biological, and chemical systems may not be well studied or understood. Regardless of the reason that decisions are made, if the intended outcome is not consistent with natural laws, it will not take place.

G. Socioeconomically constrained: Even though we can show a high degree of certainty for a particular outcome of a decision, it may not be possible to make the most cost-effective or environmentally sound decision. This may be due to insufficient capital, lack of credibility of the scientific results in the eyes of the policy maker or the public, strong economic or political forces that could gain from a different decision, breaking of culturally accepted norms or taboos, or any of a number of other social and economic variables.

V. Conclusion

The technological environment is changing rapidly. As it evolves it will be increasingly able to support the development of virtual DSS. However, there are specific technological changes that must take place during that evolution to ensure the appropriate technological environment for development of efficient and effective DSS. The elements of the decision environment, on the other hand, are likely to be similar to what they are today. The major change will be that there will be more people in and out of government able to conduct analyses and contribute more informed opinions to the debate on a wide variety of technically complex issues regarding the environment, resource management, development, etc. Sophisticated DSS's will become increasingly available. Virtual systems will be able to be built rapidly and on the fly, will provide a less expensive alternative to custom-built, stand-alone systems and provide more extensive access to information and analytical models anywhere on the Internet.

Acknowledgments
The author acknowledges assistance from Debra Cruse, Gary Fisher, Barbara Poore, and Martha Power for their comments on earlier drafts of this paper. Any errors or omissions are the sole responsibility of the author.

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Table 1. Some historic events in the evolution of the information age.

1822	Charles Babbage developed a working model of the "difference engine" for solving mathematical problems.
1844	Samuel Morse telegraphed "What has God Wrought?"
1876	Alexander Graham Bell made the first telephone call.
1892	There were 266,400 operating telephones in the United States.
1901	Radiotelegraphy was established across the Atlantic Ocean.
1934	The United States Communications Act of 1934 was enacted.
1953	IBM unveiled the Defense Calculator, its first computer.
1960	Echo 1 was launched by the United States, the first civil telecommunications satellite. The first meteorological satellite, TIROS-1, was launched.
1962	The first intelligence remote sensing satellite was launched.
1968	Intel Corporation was founded.
1971	The Canadian Geographic Information System became operational. *Management Decision System* was published, describing an operational computer-based system for decision making.
1973	The Ethernet connectivity system was developed.
1975	Bill Gates and Paul Allen founded Microsoft.
1981	IBM announced the PC (personal computer) with 64KB RAM, 40KB ROM, one 5.25" floppy disk drive, and PC-DOS 1.0 for $3000. The color version was priced at $6,000. Fifty-thousand units sold in the first eight months.
1985	The first satellite telecommunications link was made to the South Pole.
1989	Intel announced the 486 chip (1.2 million transistors). There were 50,000 Internet hosts.
1991	The World Wide Web was released.
1993	Intel introduced the Pentium processor with 3.2 million transistors.
1994	Executive Order 12906 was signed, requiring United States federal agencies producing spatial data to comply with standards for metadata and data transfer.
1996	United States Congress enacted major revisions to the Communications Act of 1934.
1998	The price for new personal computers dropped below $500 for the first time in the United States.

Supporting the Decision Process: What Can We Hope For and Expect from DSS's?

Dave Cleaves

I. Designing a Decision Support System

Decision support system (DSS) development should be directed at improving human resource performance and be guided by a realistic model of how people make decisions and how the context for decision making shapes decision processes. Several questions should guide the development of any system.

(a) What are the decisions we wish to support?

(b) What parts of the decision making process are we trying to support?

(c) What kind of support is needed?

(d) How will this support fit the context in which these decisions are being made?

The first question can be answered with systematic inventory of decisions by type within the agency. The last three questions require a diagnostic model of the decision process and a clear concept of decision quality.

"Support" in DSS is often presented under the auspices of improving the quality of decisions. One approach is to improve the content, or ingredients of decision, that is the information that is used in the decision process; the other is to improve the process, or recipe, through which turns content into action. As everyone knows, high quality ingredients are necessary but not sufficient for good cooking, or good decision making.

Decision making is the art and science of making choices for desirable change, in other words solving problems or capturing opportunities. Decision science literature identifies five functional components (phases) of decision making:

- **Process mapping**: deciding how the decision is made and who will make it. Decision quality is affected by the relative proportion of time spent in each of the phases of the process, the sequence in which the phases are conducted, the effectiveness of communication among people involved in the decision, and agreement on the nature of the process to be followed.

- **Problem framing**: describing the problem to be solved (or opportunity to be captured) in terms of yardsticks for success, reference points from which to mark improvement, and boundaries that describe functionally or physically how much of the situation is "fair game" for alternatives generation.

- **Intelligence gathering**: collecting and integrating information that will support problem framing, evaluation of the consequences of alternatives, and learning. Intelligence consists of many forms of information including data, scientific literature, expert judgement, recorded or remembered experience, operational studies, and others.

- **Evaluating and choosing alternatives**: comparing alternative courses of action on multiple and often competing criteria. It may require trading off one criteria for another or refashioning criteria or alternatives into better alternatives. The object is to find a "robust" alternative that improves on a number of different problem frames or integrates elements of individual frames.

- **Learning from feedback**: collecting and processing feedback from (a) the outcomes of the alternative that was implemented; and (b) the decision process itself. Learning can result in changes in any of the phases of the decision process. However, feedback needs to carefully evaluated to avoid learning that is misleading or unproductive.

Decision processes vary in their symmetry (relative proportion of time spent in different phases); sequence (which phases go before and condition others); level of consistency (logic links between one phase and another); cyclicality (iterations through the process); breadth of involvement; and the style and aggressiveness with each stage is approached. High quality decision processes:

- solve the right problems;
- clearly describe the problem, criteria, alternatives, uncertainties, and choices to participants;
- use information efficiently;
- evaluate a range of creative, relevant, and feasible alternatives;
- choose alternatives consistent with criteria and information; and
- provide for learning to improve future decisions.

Criteria for judging decision quality of individual phases include clarity, completeness, consistency, and cost-effectiveness. Criteria for overall process integration include: balance among different phases, breadth of involvement in the different phases, sensitivity to the political or organizational environment, legitimation with important stakeholders, and closure on the problem.

Context is important in decision quality. Several dramatic trends are assuring changes the decision context for land management and environmental organizations. These trends are determining the nature and the barriers to decision quality in the future and may provide clues of how DSS's can help decision processes adapt. These trends break down into influences on either complexity, conflict, or uncertainty. Each has implications for decision quality.

A. **Agency downsizing.** More decisions are triage-type allocation questions. More decisions result in having to say "No" to stakeholders and employees. Employee consequences play a large role as decision criteria. New balances have to be struck between agency survival and resource needs.

B. **Pervasiveness and domination of political uncertainties.** Attorneys and politicians have taken stronger direct hands in what used to be agency discretion. Decisions are increasingly interpreted in the way these people define success. Legal and political interpretations change rapidly and resource decisions often get caught in bigger dramas. Agency personnel collect information as much to justify and defend decisions legally as to discriminate among the substance of alternatives.

C. **Emphasis on measurement of performance.** The public is searching for concreteness and accountability. Such efforts as GPRA and the Sustainability Criteria and Indicators are examples. Broad goals have to be translated into measures, the process of which can surface unforeseen environmental problems and issues.

D. **Proliferation of procedural regulations and decision processes.** Agencies have multiple layers of planning, approval, and appeal. The processes create their own staff, interia, and public expectations. Some of these procedures conflict with each other and add ambiguity into an already ambiguous decision context. Their reporting requirements sap decision making time and energy. The solutions offered for many ecosystem conflicts and problems are, in effect, additional processes that require more effort.

E. **Loss of site-specific expertise.** Fewer agencies can afford to have local people who combine technical expertise and high-resolution intimacy to handle resource problems. Local public may know more about local areas and have more ready access to information than resource managers do. Mobilizing and applying new knowledge increasingly must be done with specialists with multiple technical assignments.

F. **Breakdown of functional dynasties.** Problems are less likely to be described in traditional functional terms (timber, grazing, wildlife, etc.). There is less money with which to build large staffs who have the power to impose problem frames on line decision makers. More decision making will respond to integrated descriptions of problems brought about by collaborative processes with the public. Timely information, as opposed to dollars, will become a more powerful currency with agencies and in the political scene.

G. **Fewer decision makers with experience in managing distributed decision processes.** Decision makers have to oversee a broader range of geographical, social, and technical processes. Decision making processes are increasingly distributed and negotiated, and are less concentrated with a decision maker who makes a final choice. Influencing and facilitating these processes at appropriate stages will become more of a challenge.

H. **Shift in conflicts**. Conflicts between consumptive and nonconsumptive users are giving way to conflicts between nonconsumptive users. Conflicts between local and national perspectives on federal resource use are increasingly apparent in the collaborative approaches to planning being conducted at the local level.

II. Decision Support Aimed at Process Phases

DSS support consists of assisting decision teams in one or more of the phases of the decision process. System developers could consider the following as potential application needs.

A. Process mapping

Self-documenting platforms for group decisions to help participants understand what has been done and what needs to done to complete the decision. These tools would "keep the books" on ongoing decision processes, codifying decision issues and progress so that transient participants and experts can quickly comprehend and make their contributions.

Facilitative prompts and queries to assist in process design and management. These systems would help human facilitators form hard but necessary questions that busy decision makers might otherwise ignore. This would include diagnostic questions that would help the decision maker match elements of the process with the nature and difficulty of the problem and its stakeholders.

A continually updated guide to interagency experts, organized by specialty, experience, and contact information. More than a directory, this would provide information to assess the state of knowledge in particular problem domains and a resource for assembling expert panels and other advice.

B. Problem Framing

Problem visualization aids, including spatial displays of data and a wide variety of options for graphic representations of abstract concepts. These systems are coming into their own in many applications, and deserve special attention in helping stakeholders specify desired conditions and decision teams find creative landscape alternatives.

Tools for helping people rapidly structure goals and measures. Goal hierarchies can be very valuable in specifying problem frames. Tools for eliciting them must be flexible and rapid enough to accommodate the iterative nature of values clarification from decision makers and stakeholders.

Online links to other efforts to solve similar problems in or outside the agency. Being able to take advantage of real-time learning could help decision makers avoid anchoring on inappropriate problem frames or ineffective alternatives.

Modularity and interoperability in the design of DSS's that would allow tools to be combined as the problem unfolded. Many problems have multiple facets which reveal themselves gradually. The problem frames themselves often change as the decision proceeds. DSS's may have to be reconfigured many times to meet the needs of the problem. A suite of easily orchestrated tools that accept each other's outputs is preferable to "one-size-fits-all" mega systems.

C. Intelligence Gathering

Support for improving the quality of expert judgment. This would include tools for eliciting expert judgment that reveal and manage biases, represent causal pathways that drive expert predictions, represent ambiguity and uncertainty, and facilitate group judgements. Decision conferencing software could be readily adapted to this task.

Decision structuring tools that emphasize information search and value. One example is network analyses and decision tree models that reveal critical information needs in complex problems. Especially helpful would be confidence rating schemes that allow specialists and decision makers to communicate about the relative strength and importance of various information types and sources. Such aids help focus information collection.

Uncertainty representation systems that communicate the nature of the uncertainty and risk in ranges of expected consequences. These tools should include capabilities to model political and legal uncertainties as well as ecological and physical ones.

Scenario development aids that help decision makers constantly rebuild and circulate alternative scenarios for strategic planning. These could be tied into Internet-based planning data and projections and other ongoing databases. The techniques of scenario planning are diffusing rapidly in the business world. Their embodiment in DSS's for agencies would help agency decision makers think through their assumptions about future trends and strategic options.

D. Evaluating and Choosing Alternatives

Prompts for eliciting and documenting selection rationale. These tools, modeled on the agencies' best decision makers and legal requirements, would systematically check multiple attributes and objectives and verify that the decision maker considered everything in his selection, including the information presented in the analysis. Documentation of this cross-check would be valuable in subsequent legal and political challenges.

Tradeoff analysis models. Choices often boil down to critical tradeoffs among several important objectives and require precise descriptions of what is being given up in the selection of one alternative over another. The consequences of these tradeoffs and who will bear them should be prominently displayed, not only for the decision maker but also for those who need to understand the decision.

Legal interpretation systems. The anticipation of legal consequences continues to drive many decisions. Legal interpretation is often ambiguous and dynamic; the decision maker is limited in her legal advice and may not have access to agency- or government-wide experiences with similar cases or legal issues when she needs it. An expert system could be built on legal interpretation and provide decision makers with probable consequences of alternative actions.

E. Learning

Smart databases that codify, catalog, and provide access to agency decision experiences. This database would keep abbreviated files on planning and project efforts and follow them from inception through legal challenge and implementation. Summaries of different types of decisions would serve as a guide for future decisions.

Chat boxes and bulletin boards that allow analysis teams and decision makers throughout the government to exchange views on ongoing analyses and decisions.

Decision Support Systems for Ecosystem Management: 2-1/2 Years of Herding Cats With a Leaf-blower

H. Todd Mowrer

Abstract

From 1995 through 1997, I served as a staff advisor for decision support systems to the Interregional Ecosystem Management Coordination Group of the USDA Forest Service. My initial charge was to provide leadership in bringing together members of the Forest Service decision support system (DSS) community (including research, application, and a broad user base) to determine the best ways to provide decision support for ecosystem management. A task group I assembled in late 1995 developed a list of criteria for evaluation of 24 existing DSS. We subsequently formed our own self-directed "DSS Consortium" to continue this work, and to develop a recognized forum for DSS coordination, integration, and development in the Agency. This activity was redirected in 1997 through the appointment of a full-time national decision support system coordinator. I will discuss the conclusions from the DSS evaluation, and other conclusions I have reached as a result of this overall experience.

I. Introduction

The mid-1990's were particularly challenging times for the USDA Forest Service. Public expectations of the agency had shifted from one of natural resource managers making their best decision based on biological science to one of direct public participation in management decisions. "Ecosystem management" was replacing the outdated emphasis on commodity production. Forest ecosystem management, it was understood, emphasized maintaining biological diversity and sustainability through understanding the complex interactions of multiple ecosystems existing across varying spatial and temporal scales. It also recognized the heretofore largely ignored social and economic dimensions. How to implement ecosystem management was not well understood, to say the least. Almost simultaneously, federal agencies were charged with "re-inventing" themselves: a time-consuming task further complicating the process of change, as organizational structures threatened to shift beneath the feet of natural resource managers.

In order to help define and integrate ecosystem management throughout the Forest Service, the Interregional Ecosystem Management Coordination Group (IREMCG) formed. This self-directed group consisted of Deputy Regional Foresters, Assistant Research Station and Area Directors, and Washington Office Staff working to bring a consistent corporate approach to ecosystem management in the public lands under Forest Service stewardship. Staff members were brought on board to begin the process of grappling with the complex problems of providing the spatial and temporal information and associated management tools necessary for the task of forest ecosystem management.

The IREMCG initially evolved around an effort to develop an integrated corporate database for plot-level information. Its first success involved the corporate purchase of contemporaneous and conterminous satellite remote sensing imagery for the first time in the Agency. Staff members for the IREMCG worked together to develop the overall schematic representation for their efforts shown in Figure 1. Additional efforts were recommended by the staff to develop consistent map themes and attributes; to categorize, assess, and recommend the types of analytical and predictive models that would be needed; and to determine the types of decision support systems or tools needed to aid natural resource managers in the overall task of ecosystem management.

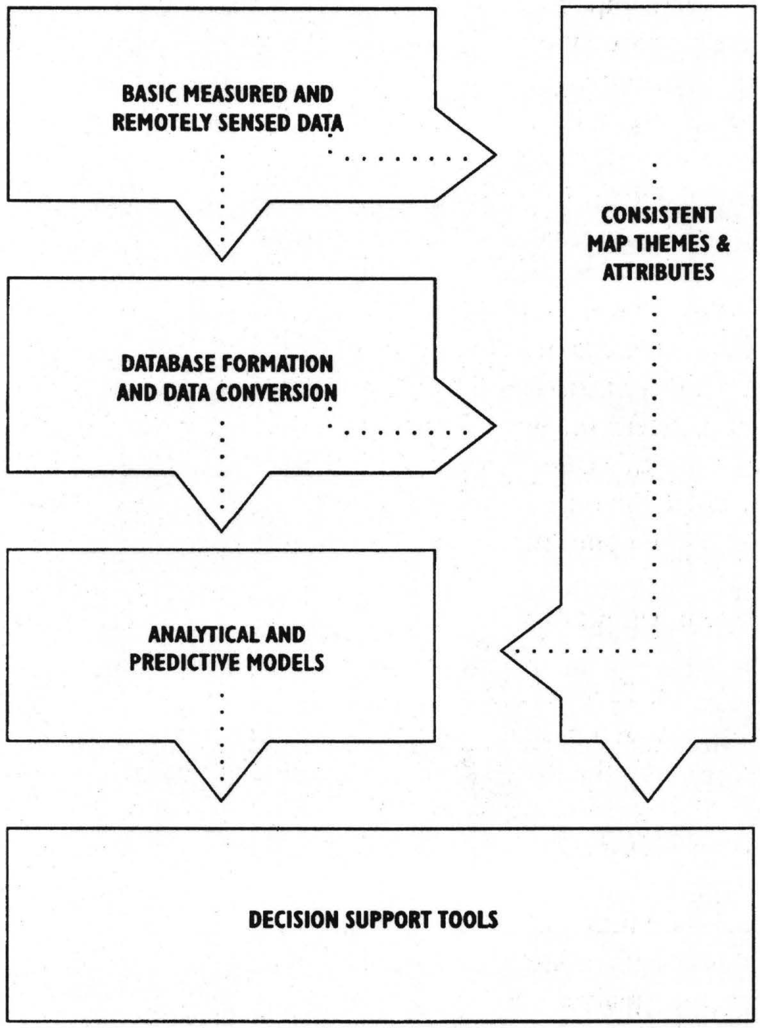

Figure 1. Information development process diagram.

II. DSS Task Team

The IREMCG formed the DSS Task Team in the late summer of 1995. The charge of the team was to enumerate the questions for ecosystem management that required decision support for ecosystem management. When I agreed to lead this team, someone asked me if I knew what I was getting into. I replied that I assumed it was much like managing research, which has been described as trying to herd cats with a broom. The respective members of the IREMCG issued a call letter for volunteers, and the resulting fifteen-member team met twice in the fall of that year. As would be expected, the most knowledgeable members of the team consisted of DSS developers and analysts with extensive experience, usually with a primary type of DSS tool. Some members of the team were non-aligned with respect to particular DSS tools, but were generally the least experienced with regard to the state-of-the-art in DSS. The simple fact of the matter was that it was nearly impossible to find experts in DSS that were not affiliated with a particular DSS or at least a particular methodology. The team recognized that before starting to develop a new DSS it is imperative that one must first determine the question that it is going to help answer. However, trying to list the depth and breadth of possible questions with which a DSS could potentially assist forest ecosystem management was an overwhelming task, given the time and resources available. After a good deal of discussion, it became apparent that the charge of the team was difficult, if not impossible to meet.

In retrospect, what was really necessary was at least an *information needs assessment*, to determine what natural resource analysts and managers thought they needed for decision support of ecosystem management. Better yet, a more thorough *business requirements analysis* could be implemented to determine the minimum subset of information and tools that were necessary and sufficient for this task. However, these terms had not worked their way into the vocabulary of the agency at the time. The team agreed to tackle a portion of the problem where we could make a meaningful contribution.

Decision Support System Evaluation

In this regard, the DSS Task Team accomplishment was substantial, and remains useful several years later: the development of a partial catalog of decision support tools for forest ecosystem management. In order to limit the total number of systems evaluated, the team differentiated between analysis *tools* and decision support *systems*. The working definition the team used for a decision support system was a computer-based system that:

supports human decision makers;
integrates data sources with modeling and analytical tools;
facilitates development, analysis, and ranking of alternative;
assists in management of uncertainty; and
enhances problem comprehension.

It does this in an interactive, easy-to-use environment with seamless access to different data sources and analysis programs (anon., 1993). As such, many individual analytical tools may be integrated under a single system to accomplish tasks such as temporal and spatial modeling, optimization, and visualization, for example.

Input was solicited from developers of DSS systems that team members felt were appropriate to support ecosystem management. It was decided that, in the interest of efficiency, DSS developers would provide the evaluations themselves, rather than the team providing an external assessment of each system. To minimize bias, the team and the other developers would review the total document for accuracy and consistency. In all, 24 systems were evaluated. Forty-eight questions were posed by the team, covering seven basic aspects of DSS tools for ecosystem management: system scope and capabilities; spatial issues; basic development and status; inputs and outputs; user support; performance; and computational methods. By comparison, Schuster *et al.* (1993) listed some 250 analytical tools for planning at the National Forest level.

III. DSS Shortcomings

Results of the DSS Team questionnaire were compiled and published as a Forest Service Research General Technical Report (Mowrer, 1997). A primary goal of the publication was to provide interested users with a document that would allow them to compare the capabilities of different systems and select one that best fit their needs. Conclusions of the comparative analysis in the report indicated that at least one system fulfilled each evaluation criterion at some level. This is not surprising, considering the makeup of the team: most members had one or more favorite tools that performed well in one or more specific regards. It was apparent that social and economic aspects were not as well addressed by the 24 systems, as were biophysical aspects. The systems evaluated did not have the ability to address ecosystem interactions at more than two spatial scales simultaneously. Nor was the capability for distributive processing well addressed, whereby multiple activities at different locations are simultaneously monitored and their effects aggregated in the real-time system evaluation. It was also apparent that the appropriate methodologies were not available to determine the correct mechanisms to aggregate, recollect, or transform data to represent the same or equivalent variables simultaneously at multiple scales. The secondary goal of the publication was to provide developers with a list of these needs for ecosystem management, not only to influence research innovations, but to aid in the pragmatic consolidation of existing systems as well.

Up until this point, independent development of DSS's in the agency, and a prior lack of agency-wide databases, data standards, and a standard computer hardware and operating system, had resulted in each DSS being developed with their own spatial and tabular data formats, and their own graphical user interfaces. Each DSS was developed and used independently, doing different things in different geographic locations. This meant that a decision support system developed in the northeast for small private landowners (where the demand was great), could not be easily revised for use in the west where demand was not great, but a substantial need still existed. Differing requirements for the data used to initiate DSS systems, along with different methods for displaying and reporting results, made it very difficult to integrate these systems on other than an *ad hoc* one-to-one basis. This state of affairs is most closely approximated by Figure 2a, wherein each system required its own unique set of data, which often had to be manually assembled by the user, and provided its own limited user interface. When a series of tools or systems were used, data output from one system had to be manipulated (often manually) to provide input to the next tool or system.

IV. Decision Support System Consortium

With the encouragement and support of the Washington Office Ecosystem Management Director and Staff, the task team formed the basis for a new open-membership group. This self-directed group, calling itself the Decision Support System Consortium, formed in the spring of 1997 with the charge of seeking ways to consolidate and integrate existing decision support systems within the agency. We met face-to-face once, and relied on conference calls and email to stay in contact. Our basic task was to recommend ways to begin moving through the integration phases in Figure 2.

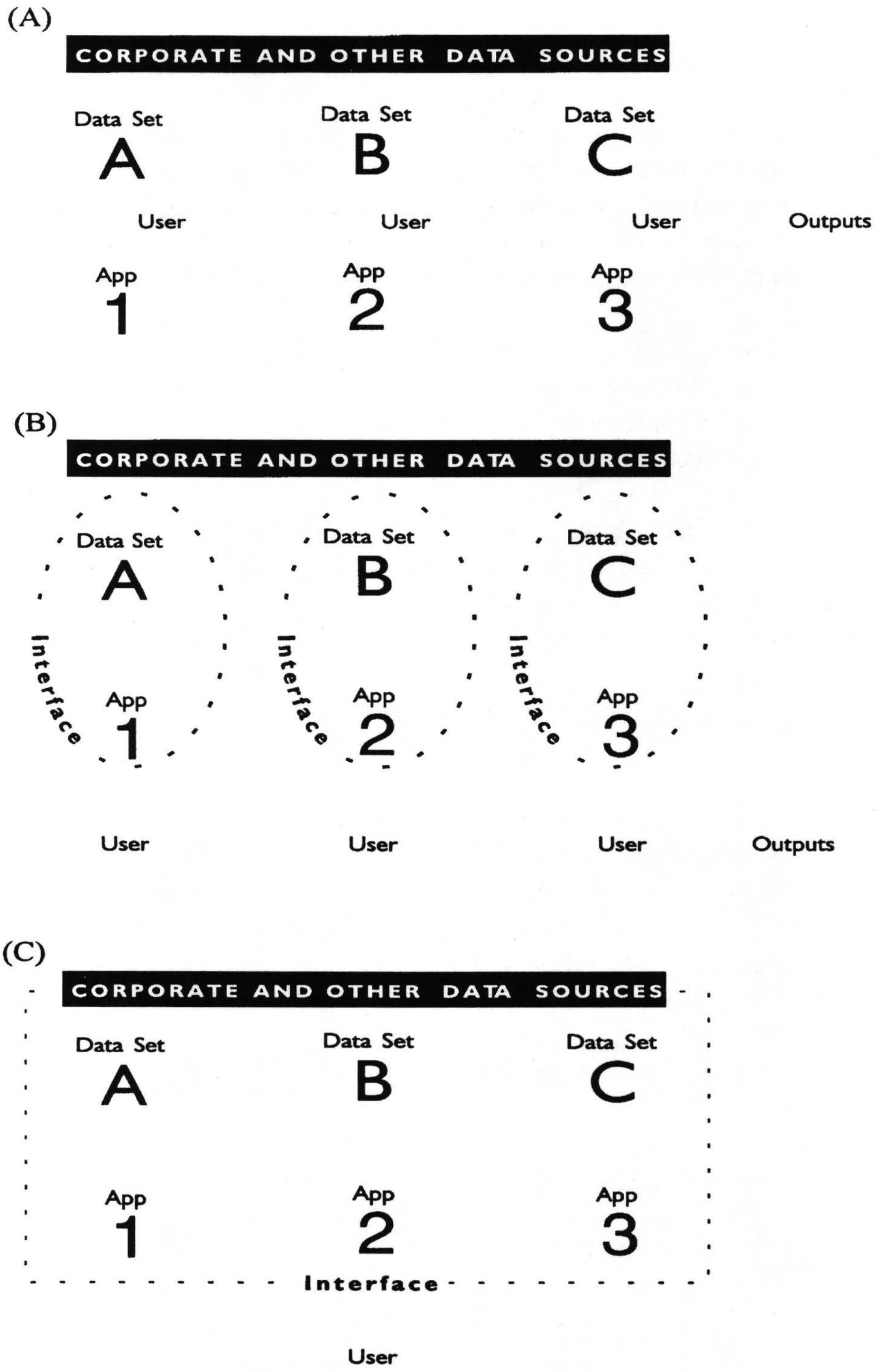

Figure 2. Increasing levels of decision support system integration from (a) stand-alone tools, to (b) tools with individual user interfaces, through (c) complete system interoperability.

V. DSS Integration and Interoperability

Figure 2b shows the next step in system integration wherein individual interfaces provide access to data and a more user-friendly interface. When systems were used sequentially, output from one system still had to be manually transmitted to the next system. Figure 2c depicts the idealized goal of true system interoperability where multiple tools and systems are modularly integrated and selected by the user from a menu-type system. Data inputs and outputs are transparently transmitted between systems and available for visualization or tabular output without additional manipulation.

Interoperability has been defined as the ability of a computer software application (decision support system, analytical tool, database access engine) to provide services to, and accept services from other applications, and to use these services in a manner so as to enable them to operate effectively and seamlessly together (DMSO, 1997). Such a capability is accomplished under a "high-level computer architecture." Currently, three such high-level architecture implementations are under way: by the Defense Modeling and Simulation Office (ibid.) and a second by Argonne National Laboratory (DIAS: Dynamic Information Architecture System, 1997). Within the Forest Service, a third ongoing effort[1] holds great potential for interoperability using existing off- the-shelf software on Microsoft's Windows[2] platforms. A preliminary proof-of-concept implementation has been constructed, and formal implementation is under way.

The desired future scenario recommended to the agency by the DSS Consortium at the June 1997 Ecosystem Management Corporate Team meeting at the agency headquarters in Washington, D.C., was to work toward a common interface and common access to different data sources. For the USDA Forest Service, these would include Oracle databases, a flexible choice of analysis and report generation and display modules, and spatial analysis and visualization through Arc/Info and ArcView GIS. The goal was a seamless integration of DSS modules, which satisfied the to-be-determined interoperability specifications, across platforms and operating systems. The benefits of such an outcome included the potential to work seamlessly across Forest, Regional, and Agency boundaries, the ability to legally defend the tools and procedures used uniformly throughout the agency, and the ability to integrate additional information and refine project goals with minimal effort.

In order to move in this direction, it was recommended that the "rapid application development" process be used, whereby overall system integration would be accomplished incrementally by repeating the "build a little, test a little" cycle, fine tuning the final product through user feedback throughout the development process. This process also had the advantage of providing intermediate products and evaluation points. If necessary, the project could be

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1 Personal communication: H. Michael Rauscher, USDA Forest Service, Southern Research Station, Asheville, NC

2 Use of a brand name in no way constitutes endorsement of a product by the USDA Forest Service, and is provided solely for the convenience of the reader.

terminated at any of these intermediate points and still provide a product.

To determine what level of integration and interoperability was feasible for decision support systems for natural resource management in the agency, an analysis of the current situation would have to be accomplished by someone knowledgeable in the field of open systems design and high level computer software architecture. If interoperability was feasible, then specifications would have to be developed for a high-level software architecture establishing intercommunication protocols and control systems for interoperability between component DSS modules (written in different computer languages) and data sources (principally from Oracle, but potentially in any format). DSS components and databases could reside on the corporate IBM system, on personal computers, or potentially on the World Wide Web. These interoperability specifications would serve as the goal and end point for the rapid application development cycles.

It was apparent that the feasibility study and recommendations for a high-level architecture was too complex to be developed within the agency, because few, if any personnel had the necessary skills. Even if these people could be identified, it was unlikely they would be available to accomplish the task. In order to succeed, such an effort would have required cross-disciplinary support and cooperation between numerous national staffs and the DSS developers themselves. These bureaucratic barriers, the lack of an applicable research reward system, and competing professional interests contributed to the challenge of "herding" these disparate interests in a unified direction. I wrote a request for proposals for a feasibility study on decision support system interoperability[3], and some funds were available at the time. However, an agreed-upon shift in responsibilities from the IREMCG to the Washington Office Ecosystem Management Staff eliminated the need for the IREMCG staff and obviated these initiatives.

VI. Conclusions

It is somewhat mollifying to realize that the impediments listed above are not unique to the Forest Service. In her book, Cook (1996) notes that, "...the demand for standards will probably not come from your internal information systems departments, all of which have their own proprietary approaches to protect. ... Internal information systems organizations are basically vendors of proprietary approaches to software and database development within the enterprise." In federal agencies engaged in the management of natural resources, not only is there an internal information systems organization, but separate DSS's are developed by different research and management units scattered throughout entire agencies. Many, if not most of these DSS's are developed by people with excellent biological credentials, but with little or no formal training in information management, decision theory, or software design. Cook further notes that "the majority of resistance [to information standards and interoperability] will come from people who assume that information architectures and their standards will eliminate their

[3] Document on file with the author

jobs." In the federal sector, however, it is more likely that one would have to abandon current goals or shift career paths, which should be somewhat less threatening. However, "turf" remains a major stumbling block to standards implementation and interoperability. She further states, "standards emerge as necessary when uncertainty in the customer community over proprietary approaches slows down industry growth, forcing vendors to work together to identify and support industry standards." Private industry, however, has the ability to respond to market changes much more quickly and flexibly than do federal agencies. Moreover, those engaged in DSS development within a federal agency may view information standards and interoperability as loosening their internal monopoly and increasing competition. The bottom line here is that, in order *for interoperability to be successful in an organization, it must be supported, and enforced if necessary, from the highest levels*. Too many organizational impediments exist for *ad hoc* "skunk works" or "grass roots" efforts to succeed on their own.

Moreover, achieving interoperability in analytical tools and decision support systems actually presupposes corporate-level information standards and database interoperability. The "legacy systems" that have evolved independently and served the data needs of an agency must be integrated or replaced. It is arguable whether database interoperability and standards should be achieved first, and analytical tools and decision support systems be allowed to adapt to them later, or whether both of these efforts should develop in parallel. To me, it seems most efficient to allow both to proceed in tandem, as agency information needs include the interpreted data that results from the output of these tools and systems. Not only that, but the data needed to initialize a decision support system must be in the corporate database, so it seems reasonable that DSS developers should have some influence on its content.

It is also very important to note that the entire information re-engineering process is based on the prerequisite of an information needs assessment or business requirements analysis. For natural resource information in the Forest Service, this would be an extremely costly and time-consuming task. And here again, the skills to accomplish it are not available within the agency. The whole resource information integration process must be an open one, throughout the entire the agency. If not, the inherent risk is that the corporate database and the accompanying support infrastructure will not be open to the fair assessment and adoption of new decision support systems if they are developed outside of that infrastructure.

We have bought into a high level of technology with GIS, remote sensing, highly normalized distributed databases, and standardized computer hardware and operating systems. These can not be used efficiently without the application of equivalently sophisticated information management techniques and methodology. Natural resource managers talk of the "80/20" rule, wherein 80 percent of the problem can be solved with only 20 percent of the total possible investment. There is another 80/20 rule that indicates 10-20 percent of the total project budget should be allocated to purchasing the hardware and software. The other 80 to 90 percent are necessary to set up the infrastructure to collect and manage the information. These two rules don't mix! We can not spend 20 percent of the budget for an information management system on hardware and software, and expect to take care of 80 percent of the overall problem, if we do not invest in the high-level expertise necessary to efficiently utilize the initial investment. These skills include software engineers, system administrators, database experts, and other information management specialists who do not come cheaply. Regrettably, many cost/benefit analyses only cite the "tip of the iceberg" and do not recognize these hidden costs to implementing new technology.

Change comes slowly and causes stress in any organization, particularly when it is forced from the outside. To meet this challenge for the 21st century, we must learn to operate in a technologically, socially, and politically sophisticated arena for decision making on public lands. We must work to facilitate seamless management across administrative and ecological boundaries, promote uniform and more defendable decisions, and expedite analytical processes where essential skills are in increasingly short supply. To implement and maintain the level of information systems complexity that is required for natural resources management, biological scientists can no longer be efficiently "retreaded" to assume technical tasks, as they have been in years past. We must corporately embrace the goal of database and system interoperability, and foster a new generation of natural resource specialists that understand techniques for information management, conflict resolution, and decision theory, as well as the biological sciences.

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Decision Analysis:
A Tool to Make Impact Assessment Work

Deena Larsen

I. Introduction

A popular cartoon shows a professor writing complicated formulas on a blackboard, adding an empty box where "a miracle" occurs, and arriving at the right answer. Making decisions seems to follow the same logic: we compile a lot of information about the impacts and step back to wait for the miraculous, right answer. Often, impact assessment becomes an ineffective afterthought. The information and insights gained either are not relevant to the decision or are not considered. This is not an effective way to solve problems. Rather than a miracle, disaster is more often the result. Various groups trying to use the same limited natural resources come into conflict. Confrontation within planning processes leads to chaotic approaches, second guessing, lost momentum, delays, and impasses.

Impact assessment, including public involvement and environmental impacts, should be so deeply integrated into an effective planning process that the question, "What does it cost for these activities" becomes meaningless. The planning process cannot function without these activities. Impact assessment must be considered as part of the approach and process from the beginning rather than as an add-on, if the planning is to succeed in solving problems.

A simple, systematic approach to planning is needed to anticipate and solve problems and manage natural resources. The impacts that will truly influence a decision need to be assessed, and these results need to be documented and considered in a rational decision process. We must ensure that decision makers and affected groups understand political, economic, social, environmental, and technological dimensions of decisions. However, managing the process to involve all stakeholders is only the first step. They must also understand how decisions are made to evaluate these impacts and see what the decision will ultimately mean.

The Bureau of Reclamation developed a workable, flexible planning tool to help replace planning regulations that have been eliminated. The Decision Process Program provides rationales and common sense steps so agency managers and citizen groups can say, "We are doing it this way and here is why." This recommended, but non-mandatory tool keeps the effective elements of planning while allowing programs and processes to follow a flexible, comprehensive framework for their decisions. The process and tools are explained in a guidebook (subtitled "How to get things done") and accompanying Website (http://www.usbr.gov/guide), applied in teams, and taught in formats ranging from brief overviews to courses for facilitators.

This approach is highly adaptable for a wide range of projects and programs and can apply in any decision that involves multiple groups with varying interests.

II. Development History

A. The Initial Situation

Reclamation is an agency within the United States Department of the Interior. Reclamation has played a key role in developing water for the arid lands in the American West since 1902. After developing these lands, our mission changed from building dams and other water and power infrastructures to managing water and related resources in an environmental and economically sound manner. To do this, we provide assistance, technical expertise, and funding for programs to Federal, state, and local organizations, including irrigation districts, water boards, water user associations, environmental groups, and Native American tribes.

Reclamation has faced and continues to face changing social values, complex environmental concerns, heightened competition for scarce resources, and cutbacks in federal spending. Building dams and other facilities affected the environment, raising issues such as **anadromous** fish passage; instream flows for fish; as well as the effect of regulated flows on drought, recreation, and cultural resources; water rights; and water use for agriculture, municipalities and industry. Our citizen and client base is widening; our partners are changing. Our constituency has broadened to include a wide variety of cultures, such as Native Americans, the fishing industry, business, and environmental groups. We must work within a wide network of stakeholder groups to manage natural resources as a community.

To meet these new challenges, Reclamation is changing its culture, policy, organization, and procedures. In 1994, Reclamation radically restructured its goals and business practices to focus on new objectives such as water conservation and reuse, river basin management, environmental protection, fish and wildlife enhancement, sustainable ecosystem development, and wetlands improvement. This reorganization involved a thorough reevaluation of Reclamation's relationship to the citizens it served. These changes are very similar to the ways government agencies in other parts of the world are changing their relationships to the citizens they serve.

To ensure that impacts are effectively considered in this changing culture, Reclamation worked to provide a policy and institutional environment that would work with local institutions, non-government organizations, and water user groups. Reclamation transformed its decision making levels and responsibilities to forge effective, operational links and partnerships with the public sector, the private sector, and community groups by:

moving decision making responsibilities to the lowest possible point in Reclamation;
eliminating internal planning regulations and other mandatory requirements; and
giving government staff more flexibility in planning and managing programs.

However, these changes were not enough to automatically ensure effective, implementable community solutions. Participants in all Reclamation programs had to fully understand how impacts were considered in government decisions. In turn, these citizen and client organizations needed to be able to communicate the changes to their constituencies and their decision makers. To work in today s complex, interrelated world, government teams must understand impacts and incorporate impact assessment into the decision process. This analysis helps teams cover all contingencies, develop a wide range of options, and evaluate alternatives to find the best fit for their situation.

Traditional planning methods often took 10 to 20 years to move frrom idea to reality — an increasingly impossible time span given the pace of change today and the immediacy of the challenges at hand. We need much faster response times to address habitats for quickly vanishing species, water quality and quantity issues for growing populations, and other pressing issues. This is clearly the decision environment worldwide.

B. The Change Process

To promote effective analysis and consideration of impacts, Reclamation first had to explain an effective decision process and apply it with a wide variety of teams. Rather than implementing the changes through a series of regulations and constraints, Reclamation chose to carefully provide the basis for decision making in a discretionary guidebook and accompanying training. This adaptable, rather than regulatory, approach to problem solving allows teams and managers to tailor the guidance to their processes and needs. Participants can easily learn the approach while applying it to an ongoing decision process. They can then apply the process in other situations — in the U.S. and worldwide, in decisions as varied as administrative, regulatory, resource management, and individual.

The authors were asked to develop an easy-to-understand decision process that would work with many different cultures, situations, and communities. The authors consulted with more than 150 contributors. These contributors, both national and international, come from all levels of Reclamation; other federal, state, and local governments; and consultants, academics, and private citizens. This process is based on what works. The process thus ensures a holistic consideration of impacts to the ecosystem and human environment. While the guidebook covers politics, policy, and partnering, it focuses on how to solve problems through reasonable, sensible, and responsible actions. The guidebook and training emphasize:

involving all affected groups and individuals equitably;
avoiding wasted effort and expenditure;
recognizing change and planning for sustainable solutions; and
documenting for citizens and decision makers.

C. The Outcome

The changes within Reclamation have been drastic; however, the Decision Process Program has resulted in changes that were more easily implemented, less costly, and more in line with our mission. The guidance outlines a workable alternative to traditional planning processes to ensure that all elements of planning are considered within today's time frames. Moreover, the program stresses monitoring and implementation to translate solutions into reality.

The guidebook has been widely distributed for use and comment. The authors have provided general training on the steps and concepts in Reclamation, other government agencies, and private organizations. The authors found that the most effective way to train is to apply the process in a team meeting for an ongoing program. This one-day team meeting not only provides an overview of where the team is going, but helps participants use the approach in future meetings and projects. Two people with diverse backgrounds facilitate the meeting so the team can accomplish their tasks and arrive at solid, well-based group decisions. An additional day of training for team leaders and facilitators develops facilitation skills so they can lead other teams through the process. This "train the trainers" approach allows the greatest flexibility for the widest variety of programs for government agencies, irrigation districts, environmental groups, and water user associations, etc.

Reclamation has used the guidance in decisions ranging from offices facing fifty-percent reductions in staff with expanding responsibilities, to long-term water resource management planning teams, to individual decisions on careers to concerns of citizens, and water user groups. The Decision Process Program directly serves Reclamation professionals, cooperating state and Federal agencies, consultants, and stakeholders involved in collaborative decision making in many areas, including:

operation decisions;
resource management planning;
public involvement and participatory management;
water conservation and water management;
construction, operation, and maintenance;
environmental compliance, including endangered species recovery;
human resources; and
water user association development (institutional and physical).

The steps discussed in the guidebook provide practical guidance on working with groups to meet needs, solve problems, and manage resources. The approach saves money by focusing research on what is needed to solve a problem. These methods thus benefit all citizens directly or indirectly involved in or affected by Reclamation decision processes.

D. A Summary of the Decision Process

While the guidance is flexible, the basic principles remain essentially the same. A systematic framework helps display and analyze simultaneous steps, conflicting perspectives, and multiple disciplines. This provides a full, balanced picture for effective decision making.

Private organizations, non-profit organizations, businesses, academic institutions (including Native American colleges), other government agencies, and agencies and organizations in both developing and developed nations have requested copies of the guidebook. Groups have used the approach in their own programs, including career counseling for homeless, office restructuring, new product development, and long-term, sustainable watershed management decisions.

E. Simultaneous Decision Analysis

Previous approaches to decision making have had a checkered history because they assume planning is linear. The decision process is not a linear, neat package. In fact, it isn't even one process. Instead, one process to identify and handle problems or changes starts in the midst of another. Smaller processes determine one aspect of analyzing data, documenting and communicating effectively, or refining a component, while larger processes cover the overall solution. These processes are simultaneous — not separate actions. Information for different steps may come in at the same time, and can be confusing.

Further, analyses and decision making do not progress directly from point A to point B. At times, it may seem to a decision making team that it has skidded backwards to a "previous step." In fact, such repetition is not only justifiable, it is advisable. Each repeat step leads to a broader, clearer understanding of issues and participants. New players (interest groups, core team members, politicians, and others) enter the process; new data lead to different evaluations.

The Decision Process Program provides a simultaneous approach to decision analysis. Decision analysis categorizes impact assessment results into an overall framework. By ensuring that impact assessment and communication is part of every step, decision makers and those affected can cooperatively reach sustainable solutions that work. While decision analysis is a constant process, clarifying it at critical junctures can avoid conflicts and delays and keep participants informed. This approach also focuses impact assessments to ensure the data and analyses are relevant to the decision.

F. Decision Process Steps

Ten steps provide a format to decide approaches, determine analyses, and systematically solve problems. This framework quickly shows what information is available, what is relevant, and what is needed. Table 1 summarizes the steps presented in the guidebook and Web site. There is nothing sacred about the number of steps — only the actions required. In fact, most of these steps will be applied simultaneously. Teams use a worksheet or flipcharts to write down information for all steps at once. The guidebook also covers concepts such as identifying decision makers, measuring success, communicating, working with partners, incorporating political concerns, defining priorities, planning for change, and recognizing risk.

Table 1. Summary of the Decision Process Steps

Before Funding	Identify and define problems and examine contexts to get funding and authority.
Before Starting	Make sure the problem is defined, the context and ground rules are agreed on, and players are ready. Determine who will make decisions and how they will be made.
Step 1: Needs	Examine the existing knowledge base and gather additional necessary data. Identify the area of influence (problem shed), the existing limitations (legal, physical, etc.), and the issues and concerns through public involvement and scoping. Catalogue the various perceptions of needs from various publics.
Step 2: Objectives	Determine the objectives — those needs that your process may help to meet. Spend some time separating out underlying real needs from stated positions. The rest of the decision process will focus on meeting these objectives.
Step 3: Resources and Constraints	Figure out what you have to work with and what the boundaries of the study are. Determine the relationships and influences among available resources (physical, social, and political). These resources provide a reality check C they determine how you will be able to meet the objectives.
Step 4: Options	Brainstorm options or components of solutions. These will provide multiple ways to address each objective. Consider all options presented at this point — they'll be narrowed down later.
Step 5: Screening Criteria	Determine standards that each option must meet in order to work. Use these to weed out fatal flaws. Apply the criteria to each option consistently to develop a set of viable options.
Step 6: Alternatives	Combine options to form alternatives. Develop a wide range of alternatives, including no action. Check each alternative to ensure that it meets the objectives.
Step 7: Evaluation	Develop evaluation criteria to rank the alternatives. Perform analyses and weigh tradeoffs to compare alternatives.
Step 8: Selection	The team presents the analyses to the decision maker and the public. The decision maker then selects a workable alternative and explains the rationale to the public.
Step 9: Implementation	Identify and fund responsible implementers to carry out the decision. Find and communicate with newly affected and interested publics.
Step 10: Follow up	Make sure the solution continues to work by providing for maintenance and operation of physical structures and administration of institutional solutions. Examine the situation and modify the solution when necessary. Afterwards, discuss the decision process and let others know what worked and what didn't. Carry these lessons over into future problem-solving efforts.
Celebrate Success	You deserve it.

A summary tour of the Web site is available at *http://www.usbr.gov/guide/execsum.htm*. This tour provides links to further information on the main concepts and ten steps.

G. Conclusion

A systematic, flexible approach to decision making is needed to put any results from impact assessment into context. Rather than relying on miracles, an organized approach can show how and *why* decisions were made, thus building support for actually solving the problem.

The Decision Process Program can be replicated in any organization that faces complex decisions. It is particularly suited to situations with limited resources, (e.g., low funding, short deadlines) or complex analyses (e.g., multiple interest groups, interrelated impacts). A wide range of examples and applications are presented in the guidebook, making it relatively simple for other organizations to adapt it to their own purposes. The concepts, examples, and processes help organizations effectively manage resources and solve problems. The authors have taught the decision process to representatives from various organizations who have successfully applied the steps to their own situations.

For Further Information:

Suggested reading, bibliography, and contributors are listed in the guidebook and Website. Copies of the guidebook can be obtained by writing to The Decision Process Program, D-8250, Bldg 67, Denver Federal Center, Denver Colorado, 80225-0007; by calling (303) 445-2584; or by emailing dlarsen@do.usbr.gov.

Measuring Stakeholder Objectives for Public Lands

Deborah J. Shields, Wade E. Martin, Ingrid M. Martin, and Holly W. Bender

Abstract

Most public lands in the United States are managed for multiple uses. Given that not all uses are compatible, choices must be made, which inevitably leads to conflict. We have developed a framework for land management that views the interaction between society and land use decisions in a hierarchical manner: basic held values determine social objectives which in turn drive management decisions. To test this theoretical construct, the traditional values-attitudes-behaviors framework was revised to reflect the mechanisms linking values to public and management behaviors. A survey instrument containing values, goals, attitudes, and behaviors questions was developed and mailed to users of an urban National Forest in the Rocky Mountain region. The theoretical construct was verified by the structural equations model built using the survey results; i.e., goals mediate between values and attitudes. We then tested for consistency among responses for selected subsets of the population by classifying the full data set into subsets of responses exhibiting similarities. Four value clusters, three objectives clusters, two attitude clusters and three behavior clusters were identified and characterized. Cluster membership was tracked through the four sections of the data to determine whether individuals holding similar values also espouse similar goals and attitudes and behave similarly. Although there was strong support for this hypothesis, we also found that almost all groups had certain behaviors in common, which suggests that results of this type could be used to identify community of interest, as well as fundamental differences.

I. Introduction

During the early years of the Forest Service, line officers in the field were accorded almost complete responsibility for decision making. Management was based upon their judgments about the condition of natural systems and their understanding of public opinion (Pinchot 1947). Negative, and particularly emotional, public reactions to forest management practices were routinely dismissed as irrational (Vining 1991). Formally incorporating stakeholder objectives into the land management process was deemed unnecessary at a minimum, possibly counter productive, and probably inappropriate.

This situation has changed dramatically since the 1960's. The National Environmental Policy Act of 1970 (NEPA), and subsequent guidelines written by the Council of Environmental quality afforded the public a means for active involvement in land management. The Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA) directed the agency to develop a national program and to plan for the future, while the National Forest Management Act of 1976 (NFMA) mandated Forest-level management plans. Plans were to be developed with the input and involvement of the public.

The Forest Service consequently began moving toward a more participatory management style. The ensuing discussions of ideas such as New Forestry (Franklin 1992), ecological forestry (Salwasser *et al.* 1993), and New Perspectives (Jones and Bartlett 1993) gradually evolved into a commitment to ecosystem management (Robertson 1993). Ecosystem management is a philosophy that unites the concept of sustainable ecosystems with the need and desire for commodity production, environmental services, and other outputs from natural systems. Consistent with NEPA, RPA and NFMA, one tenet of EM is community and stakeholder involvement in forest planning. The current Chief of the Forest Service, Michael Dombeck, has stated that he views collaboration [with the public] as a core value for the agency, along with health of the land, good stewardship and accountability.

Incorporating stakeholder concerns and goals[4] for public lands into forest planning and management presupposes knowledge on the part of the Forest Service as to what people actually want. Moreover, as would be expected, expansion of the parties involved in management decisions has dramatically expanded the possibilities for and areas of conflict. Conflicts occur for many reasons. In some cases, they are the result of misunderstandings or miscommunication among various segments of the population and land managers (Vining and Ebreo 1991). But conflicts also arise because different groups have different opinions about how public lands should be managed and their respective goals are partially or wholly incompatible. In such cases, fulfilling the objectives of one group may make it impossible to fulfill the desires of another. Unfortunately, the policy goals embodied in collaborative ecosystem management do not clearly define how priorities are to be allocated between ecosystem health and societal demands when the two goals are mutually exclusive (US-GAO 1994).

What is needed is a framework within which it is possible to make management decisions that balance the sometimes competing goals of the agency and its numerous stakeholders. This in turn depends upon the availability of information on what stakeholders desire and what the consequences would be of fulfilling those desires. We have responded to this perceived need by proposing a framework for collaborative ecosystem management (CEM) that views the interaction between society and land use decisions in a hierarchical manner: basic held values determine social objectives that drive management decisions.

This paper presents the conceptual framework and reviews a few of the quantitative methods that have been developed to implement the model in the field, using the results of several field applications. The authors then introduce our hierarchical CEM framework, demonstrating how the theoretical model is linked to measurement of models. The related survey instrument is also described. Empirical results of an implementation of the survey are presented in structural equations model form. In addition, cluster analysis results on these data are presented and interpreted. We close with comments on the applicability of the tools to resource management.

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[4] The terms goals and objectives will be used interchangeably.

II. The Conceptual Framework

Ecosystem management has been described by several authors in terms of three overlapping domains: social needs, economic needs and ecological capabilities (Zonneveld, 1990; Kaufmann *et al.,* 1994; and Bormann *et al.,* 1994). A Venn diagram is typically used to illustrate such a model because there is no ranking among the three components. CEM can be thought of as an extension of these conceptual models in that it attempts to connect the social, economic and ecological spheres; however, here the elements are hierarchical and ordered, rather than being coequal (Mitchell *et al.,* 1996).

Cooper (1969) pointed out that decisions about natural resource management take place at a level of integration higher than that of the ecosystem itself. Consistent with that view, our hierarchical CEM model places basic human values (sometimes called held values) over the cultural, institutional, and economic framework within which societal goals and objectives are communicated; over assigned value measures; and over the actions which will impact the bio-physical system (Figure 1). Typical of hierarchies, control flows from top to bottom; information flows in the opposite direction. Thus, basic held values are assumed to determine the social objectives that drive land management decisions (Shields and Mitchell, in press). Implementation of those decisions leads to biophysical and social impacts and, in a fully functioning application of this model, information about those impacts would be passed back up through the levels of the hierarchy.

A measurement model was then created that mirrors the hierarchical model (Martin *et al.*, 1997). The traditional values-attitudes-behaviors framework (Homer and Kahle, 1988; Manzer and Miller, 1982) was revised to reflect the mechanisms that link values to behaviors. Specifically, we believe that goals mediate the relationship between values and attitudes, leading to a values-goals-attitudes-behaviors construct. Values, particularly with respect to the environment, are assumed to provide the motivation for objectives, attitude formation, and behavior. The objectives various segments of society espouse for public lands are derived from their held values. They reflect existing social and institutional constructs that are themselves expressions of society's held values. Objectives are also the foundation for relative valuation of alternative states of the world. Thus, attitudes, which are a way of expressing valuation, follow from objectives. Finally, personal behaviors, or at the agency level, management decisions, are the tangible evidence of attitude (Figure 2)[5].

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[5] Figure 2 also illustrates the relationship between the theoretical and measurement models and the quantified model, which is based on an objectives hierarchy framework. Interested readers are directed to Shields and Mitchell, in press.

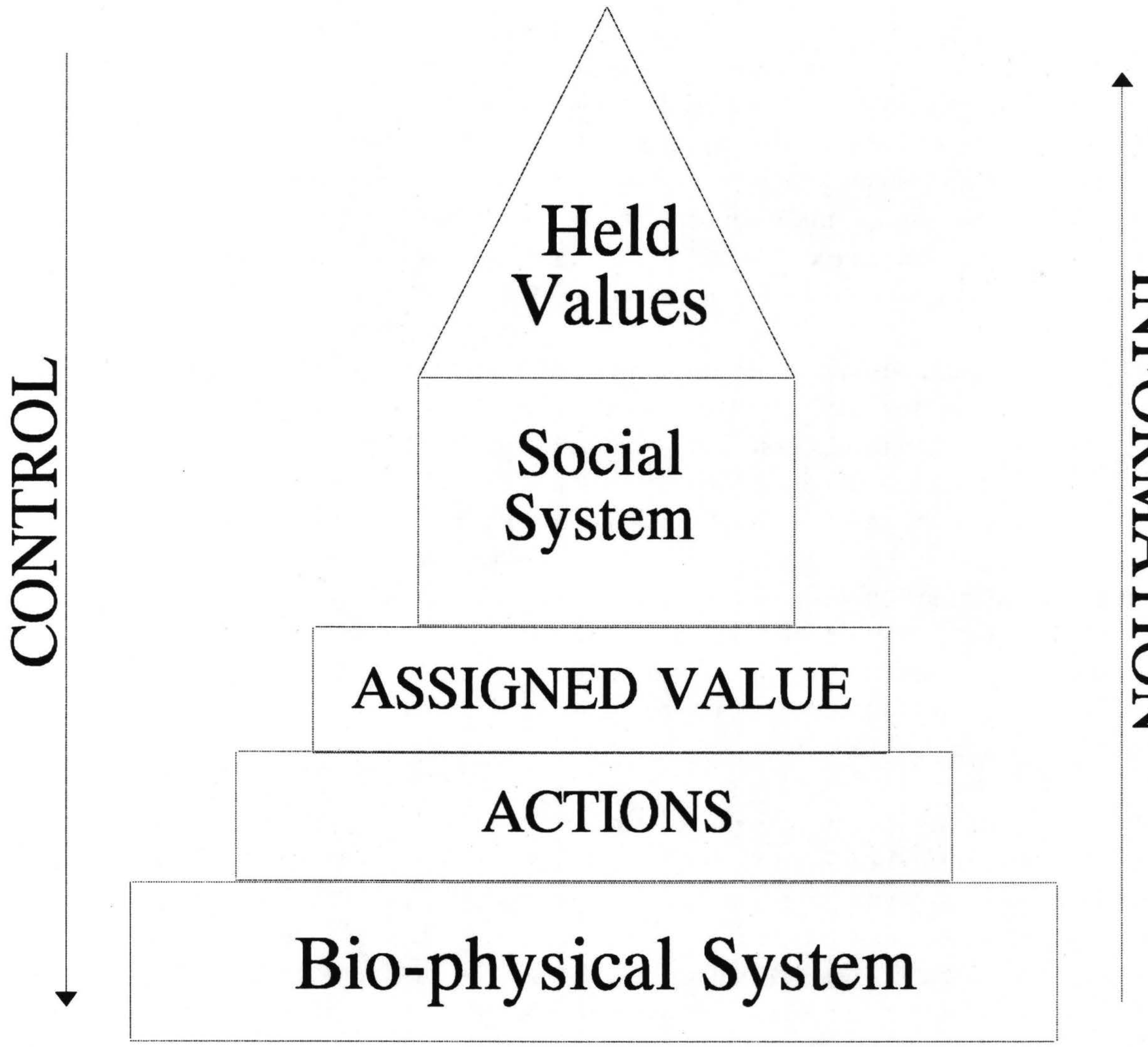

Figure 1. Hierarchical model of collaborative ecosystem management.

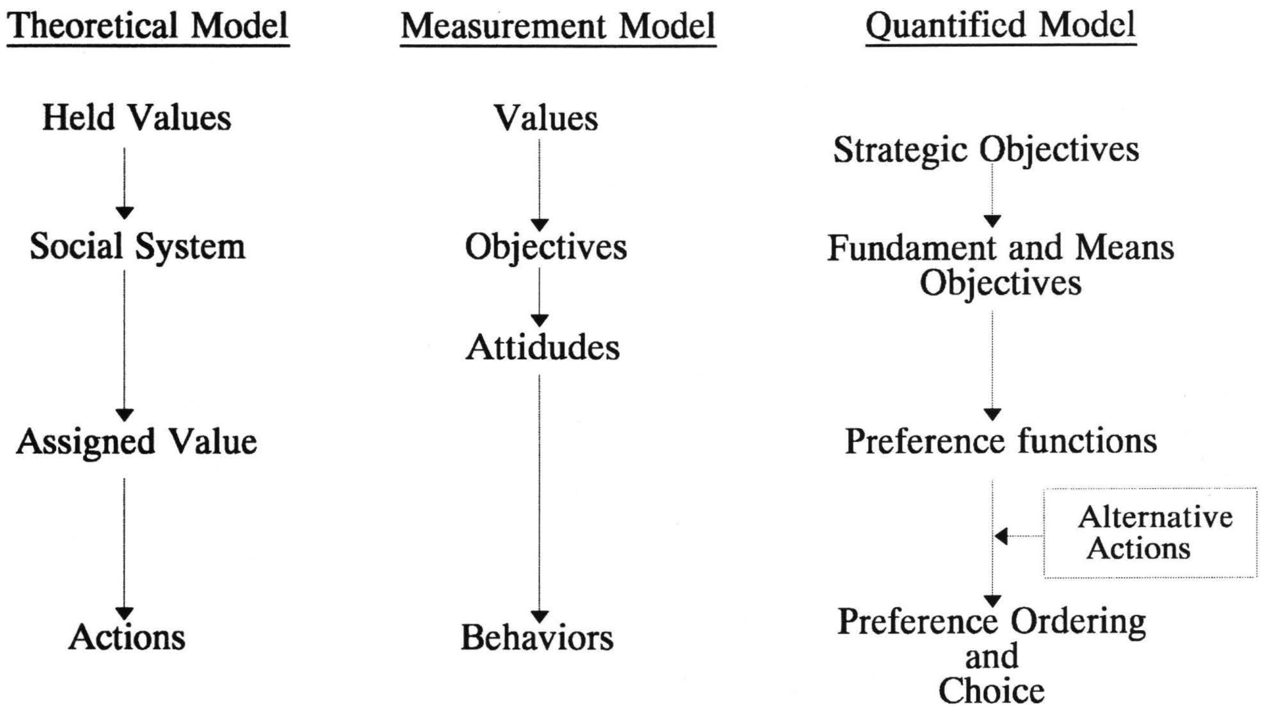

Figure 2. The theoretical, measurement and quantified models of collaborative ecosystem management.

III. The Survey Instrument

To investigate the relationships among values, goals, attitudes and behaviors, a survey instrument comprising four sections was developed. First, a set of potential value measures applicable to this study was derived from a diverse set of value scales in the psychology, economics, ecology, political science, consumer behavior, and marketing literature (Martin *et al.* 1997).

Objectives for public lands were elicited for a number of different decision contexts via interviews with public land stakeholder group representatives. The methodology for identifying objectives of the various groups was based upon the decision analysis and consumer psychology literature (Guttman, 1982; Keeney and Raiffa, 1993; Olson and Reynolds, 1983). The laddering technique was used to elicit a set of goal statements that are put into a hierarchical structure (Keeney, 1992; Reynolds and Guttman, 1988) and the resulting 31 means objectives were included in the survey in rating scale format as direct measures of the goal hierarchy. Objectives hierarchies are discussed further in a subsequent section.

The attitude section of the survey was designed to measure stakeholders' attitudes toward public land usage behaviors. Attitudes are also measured in a hierarchy, recognizing the idea that goals and related attitudes are organized from specific to general or vice versa (Eagley and Chaiken 1993). Attitudinal measures were scaled in terms of respondents' level of agreement with a specific activity, the suitability of that activity on public lands, and its potential to cause environmental damage. The final section of the survey measured respondents' actual behaviors associated with public lands, as well as general demographic information. The number of variables associated with each section of the survey, as well as Likert Scale descriptions, are shown in table 1.

Table 1: Variables and Likert Scales in the Measurement Model

Variable Name	Variable Symbol	Number of Variables	Description
Value	V	31	7 point scale
Objectives	O	31	7 point scale
Attitudes	A	61 9	7 point scale; 8 point scale
Behaviors	B	19 1	7 point scale; 1 binomial

The survey was mailed to 800 users of an urban National Forest in the Rocky Mountain region, with a response rate of 50% (N=397) for one mailing. A subset of these data were used to develop the structural equations model described in the next section; the full set was used to conduct the cluster analyses described later in this paper.

IV. The Structural Equations Model

CEM is based upon the premise that the underlying value systems held by stakeholders and managers guide the types of goals that they espouse, which in turn direct their attitude formation and actual behavior or usage patterns. A structural equations model was developed to analyze the relationships among values, attitudes, and behaviors for a target segment of public land users — individuals affiliated with environmental groups (N=210).

For each variable, maximum likelihood factor analysis with Varimax rotation was used to identify underlying latent factors associated with values, goals, attitudes, and behaviors. These variables reduced to two latent value, two latent goal, one latent attitude, and four latent behavior constructs. The first value dimension identified was socially responsible individual values, a factor that focuses on the actions, either prescriptive or normative, of the individual related to the non-market good, public lands. The second factor is the underlying dimension of socially responsible management values, which focuses on the actions of the public lands agencies (i.e., Forest Service, Bureau of Land Management). The two latent constructs for goals represented respondents' two strategic objectives. The first construct was ecological equilibrium and the second construct was access to public lands and their resources. One latent construct emerged from the attitude hierarchy, which was defined as preservation.

Finally, a maximum likelihood factor analysis of the actual usage behavior resulted in four types of usage behaviors or dimensions. The first factor was a measure of non-motorized recreation, which includes such activities as hiking, camping, cross country skiing and so on. The second factor was a measure of motorized recreation that represents such activities as dirt biking, snowmobiling, and four wheel driving. The third factor to emerge represents commercial and commodity uses which includes such activities as hunting outfitters, mining, ranching, and so on. The fourth behavior factor to emerge was consumptive recreation, which included only hunting and fishing activities. The basic difference between the four factors is the potential damage component to public lands associated specifically with the motorized recreation and commercial and commodity uses factors. During the modeling process it was determined that no significant paths leading to the behavior factor of consumptive recreation. Thus, it is evident that something other than these consumers' values, goals, and attitudes would explain why they would or would not use these types of activities (i.e. fishing and hunting). Based on this preliminary finding, the consumptive recreation factor was eliminated; thus, the final model has only three types of usage factors — non-motorized recreation, motorized recreation, and commodity and commercial uses.

The hypothesized factor structure and EQS parameter estimates are shown in Figure 3 and Table 2. The structural equations model represents an estimate of the relationships among the various latent variables derived from the survey results. As we had hypothesized, the model demonstrates that goals mediate between values and attitudes and thus supports our theoretical model of CEM. For the target group, biocentric and nonuse values are more influential for ecological oriented goals, while biocentric values are less important for access directed goals.

Ecological goals form the basis for conservation attitudes; access based goals are the basis for recreational opportunity attitudes. Both types of attitudes influence behaviors, but individuals who report that they participate in low-impact activities also espouse strong conservation attitudes and ecological goals. Individuals who report that they participate in higher-impact activities espouse recreation-oriented attitudes and conservation-based goals.

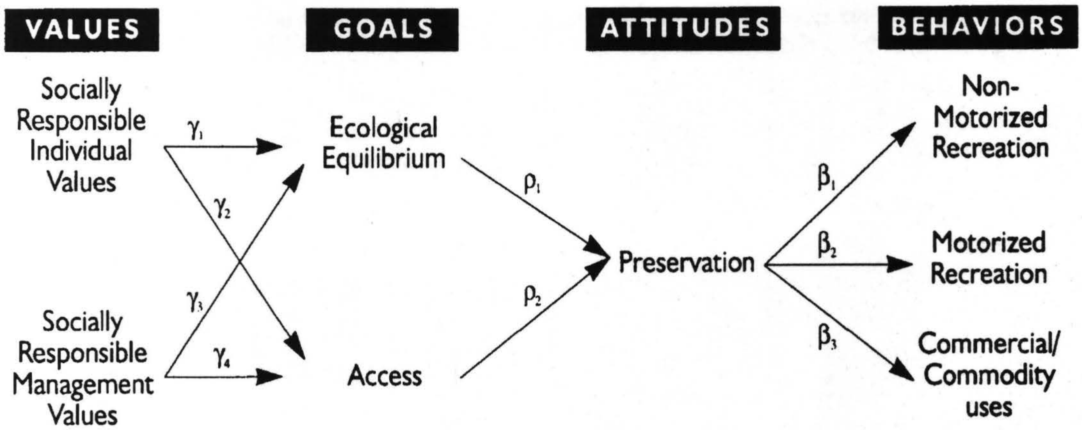

Figure 3. Values-Goals-Attitudes-Behaviors Framework.

Table 2: Values-Goals-Attitudes-Behaviors Framework: Causal Model Results

Paths	Standardized Path Coefficients	T
γ_1	0.773	14.790
γ_2	0.310	3.650
γ_3	-0.187	-4.057
γ_4	-0.421	-5.601
ρ_1	0.594	16.329
ρ_2	0.082	2.772
β_1	0.559	3.191
β_2	-0.587	-4.880
β_3	-0.148	-2.747
χ^2	156.7	
Df	19	
ρ	<.001	
AGFI	0.725	
RMSR	0.106	
Δ	0.762	

V. Cluster Analysis

Public opinion with regard to the appropriate use and management of public lands is quite diverse. This is not surprising, given that we live in a pluralistic society and that each individual's opinions depend upon his or her unique life experiences and background. Nonetheless, it is reasonable to expect some degree of consistency among responses for selected subsets of the population. We explored this theory by classifying the full data set (N=397) into subsets of responses exhibiting similarities using cluster analysis (Aldenderfer and Blackfield, 1984; Everitt, 1993; Gnandadesikan, 1977), which is defined as a set of techniques used "to identify similar entities from the characteristics they possess" (Hair *et al.* 1987, p. 2).

Values, goals, attitudes, and behaviors responses were clustered separately. Initial clustering was performed using a K-means clustering procedure, which has been shown to yield good results when combined with accurate a priori information. For the K-means procedure, cases are excluded **pairwise** to maintain the maximum number of observations in the results. Subsequently, the data were clustered using both Ward's Minimum Variance method, the Centroid cluster method, and K-means clustering based on a seed from the Ward's method. The Ward's and Centroid methods exclude observations with any missing data and all three approaches use Euclidean distance measures. Multiple cluster methods are frequently used to support the validity of clustering results (Milligan, 1980), and in this case all methods gave very similar results.

Four value clusters, three objectives clusters, two attitude clusters, and three behavior clusters were identified. These are shown in figure 4, which can be read as follows. The clusters are numbered from left to right, so that the first cluster in the V row is value cluster V1. The number in the box represents cluster membership. Hence, V1 has 18 members, and so on. The value clusters can be characterized as: V1 — strongly anthropocentric, V2 — moderately anthropocentric, V3 — moderately biocentric, V4 — strongly biocentric. The objectives clusters split along wilderness and transportation issues: O1 — in favor of new roads and against new wilderness, O2 — moderate, O3 — against new roads and for new wilderness. One attitude cluster (A1) comprised respondents in favor of the full range of multiple uses on public lands, while the other (A2) comprised those individuals opposed to motorized and commodity activities.

Behaviors split three ways. Two groups share many activities such as hiking, camping, backpacking and wilderness experiences, but split into those who also enjoy hunting, fishing, and 4 wheel drive (B1), as opposed to those (B3) who pursue mountain biking and cross country skiing. The third group (B2) participated only walking, hiking, picnicking, and automobile based sightseeing.

As previously noted, the values-goals-attitudes-behaviors framework implies that individuals holding similar values should espouse similar goals and attitudes and behave in similar manners. To test this hypothesis, we tracked cluster membership through the four sections of the data. There were several obvious trends in the responses. All 18 of the strongly anthropocentric respondents (V1) and most (N=54) of the moderately anthropocentric respondents were classified together in objectives (O1), attitudes (A1) and behaviors (B1) clusters that were consistent with their instrumentalist view of nature. Similarly, most (N=134) of the strongly biocentric respondents (V3) were classified together in objectives (O3), attitudes (A2), and behaviors (B3) clusters that were consistent with their professed environmentalist land ethic. Not surprisingly, those respondents holding moderate value sets also expressed moderate views on the objectives, attitudes and behaviors scales. They were also more likely to disperse across clusters than were respondents holding more extreme views.

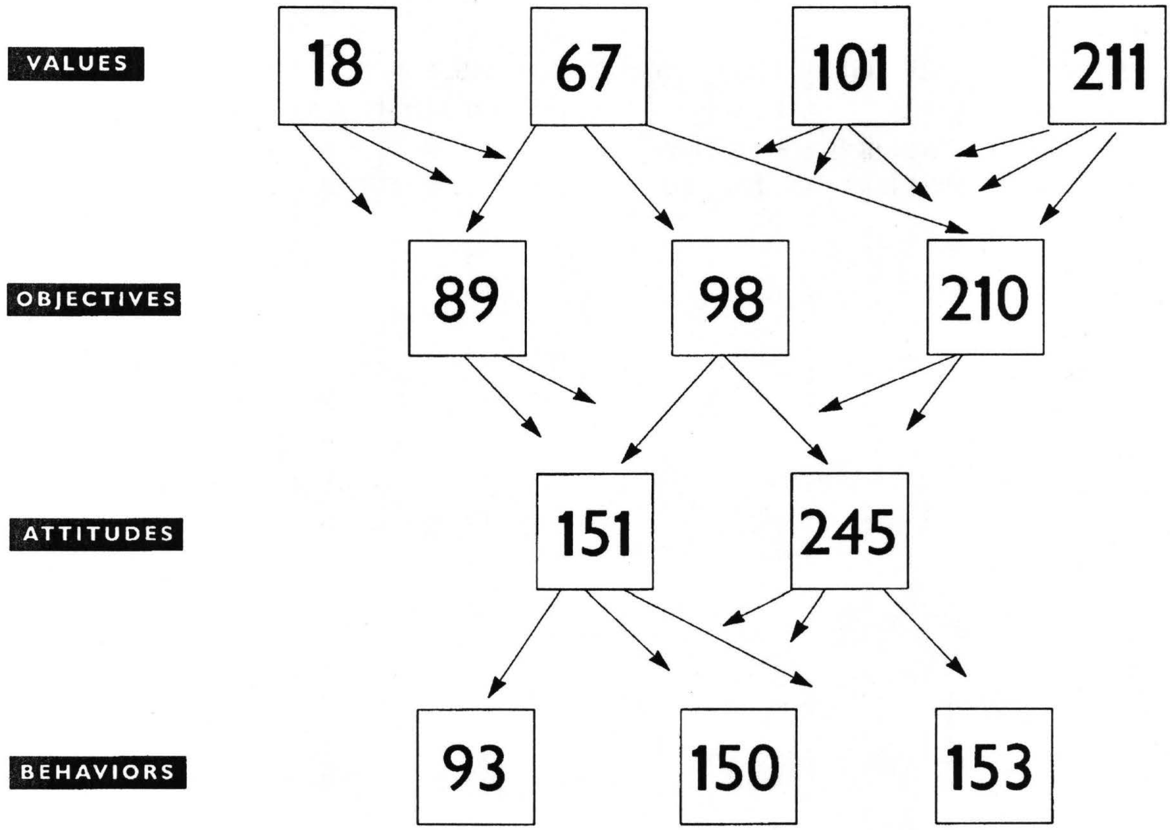

Figure 4. Results of cluster analysis.

VI. Applications and Conclusions

Planning takes place at many scales in the Forest Service. At the national level, the agency produces a Strategic Plan as required by the Government Performance and Results Act. The technical analyses conducted as part of the RPA Assessment process support development of the Strategic Plan. In addition, each Forest produces a land and resource management plan that is periodically updated. And finally, at a more local scale, Forests regularly write and administer allotment management plans, timber sale plans, and other projects designed to fulfill the goals of their Forest Plan.

Each of these levels of planning requires public input. Historically, public interaction with the agency has taken many forms, including written statements, pubic hearings, meetings, workshops, open houses, interpretive programs, surveys, and informal contacts. All of these are useful activities; however, they seldom lead to formal statements of stakeholder objectives for public lands, information which could be useful to both managers and stakeholders. The survey instrument developed as part of the measurement model of the CEM framework provides a quantitative method for eliciting information about stakeholders' values-goals-attitudes-behaviors with respect to public lands. This type of information can inform the planning process if it is collected on the appropriate scale, i.e., national surveys to support the Strategic Plan, regional surveys to support Forest level planning efforts, and local surveys to support localized management actions. At the national scale, survey results could assist in clarifying the public's goals for forest and rangeland ecosystems, information which could then be used to refine the goals set out in the Strategic Plan. In the case of Forest Plan revision, survey results could assist in determination of purpose and need, i.e., defining the problems the revised plan will be designed to address.

Issues revolving around the management of national forests and other public lands have become increasingly contentious. A primary source of concern has been the perceived or real lack of involvement of stakeholder groups in the decision making process. We feel that a process that more effectively incorporates stakeholder objectives in the planning and decision making process for national forest management has considerable potential for reducing disputes over future decisions. In addition, information on shared value sets, objectives, attitudes and behaviors can be used to identify areas of agreement among stakeholders. Consensus may be more easily attained in cases where common interests have been demonstrated.

In conclusion, the CEM framework facilitates stakeholder involvement in Agency planning, fits well within the sustainable forest management paradigm, and can inform the planning process. Although only the measurement model has been discussed here, all parts of the framework have been tested in the field with positive results. The Forest Service is committed to fulfilling the social and economic demands placed on National Forests and Grasslands by the American public to the greatest degree possible, while at the same time maintaining ecosystem health. The CEM framework and associated tools can support this challenging task.

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Overview of Some Practical Tools for Providing Decision Support Services

Brand L. Niemann

Abstract
The results of the workshops and meetings preceding the formation of the Interagency Group on Decision Support (IGDS) are available on the Web and Web-connected CD-ROM (http://cdserver.er.usgs.gov/gye.htm) as an example of practical tools for decision support services. In addition, some examples of the author's work since the February Denver Workshop have been included in this paper, namely, Science for a Changing World — The 1998 USGS Open House Web-Connected CD-ROM, a digital library of the state of the environment (http://www.sdi.gov/diglib.htm), and a GIS Starter Kit for the Southern Appalachian Area (http://www.sdi.gov/samab.htm. Some next steps are outlined for data mining with advanced exploratory data analysis and visualization tools in the EPA Region 3-Chesapeake Bay Ecosystem and developing Web "drill down" applications for map statistics and sustainable development indicators on national, regional, and local scales.

I. Introduction

The Interagency Group on Decision Support (IGDS) was formed in 1998 after a series of workshops and meetings in 1996-1997, namely : (1) Linking Science to Federal Land Management in the Greater Yellowstone Area (June 1996, Grand Teton, WY); (2) Humans in the Greater Yellowstone (September 1996, Bozeman. MT); (3) Decision Support for Greater Yellowstone Ecosystem Management (December 1996, Denver, CO); and (4) Greater Yellowstone Ecosystem Research (August 1997, Grand Teton, WY). The results of the first three meetings and workshops have been presented on the Web (http://cdserver.er.usgs.gov/gye.htm see Meetings and Workshops in Appendix A). The IGDS decided to compile the presentations from the February 1998 Workshop in Denver in July 1998, so this paper contains additional work to the present date.

The author's viewpoint has been to approach the subject of decision support not as a system, because each problem area and issue seems to require something different or unique, but as the use of a suite of practical tools to provide services. An excellent example of a model of services for Distributed Geographic Information (DGI) has been provided by Brandon Plewe, author of "So You want to Build an Online GIS" (GIS World, Nov. 1997, pp. 58-60) and the Web site at http://kayenta.geog.byu.edu/gisonline/. According to Plewe, the types of services offered by DGI are:

Raw data download (e.g. USGS GeoData)
Static maps (e.g. Virtual Tourist)
Dynamic map browsers (e.g. MapQuest)

Metadata catalogs (e.g. FGDC & ImageNet)
Web-based GIS query and analysis (e.g. GeoMedia & GRASSLAND)

A Web site for the interagency LandView work (http://cdserver.er.usgs.gov/lviii.htm — see Appendix B) has been organized according to the DGI model (http://cdserver.er.usgs.gov/lvonline.htm) (see Appendix C) which also includes a pre-FGDC compliant metadata clearinghouse.

Decision support services need to be delivered on the Web, multimedia CD-ROMs, laptop PCs, high-powered computer workstations, printed reports, and in person. However, it is a real challenge to deliver state-of-the-art tools and applications within short time frames on very limited resources in the federal government. One "solution" has been to leverage resources among several federal agencies and/or commercial firms. The examples presented by the author at the February Denver Workshop (see Appendix D) were all leveraged and continue to be leveraged to maintain and build upon them.

II. Some Recent Examples

A. Science for a Changing World — The 1998 USGS Open House Web-Connected CD-ROM

This CD-ROM supports the USGS's mission to provide the nation with reliable, impartial scientific information to describe and understand our changing world. The information is used to: (1) minimize the loss of life and property from natural disasters; (2) manage water, biological, energy, and mineral resources; (3) enhance and protect the quality of life; and (4) contribute to sound economic and physical development. The USGS uses four theme areas (namely Hazards, Natural Resources, Environment, and Information Management) to help communicate more effectively how its science information contributes to public policy issues. All of the USGS's diverse investigations in every state of the Nation and in many countries fall under one or more of these four themes. The Web-Connected CD-ROM brings together fact sheets, videos, maps, computer animations, coloring books, many of the general interest publications, and other types of information (see Appendix E) organized by these four themes. This was done to show not only what the USGS does and how the agency does it, but also the variety of information provided to the public and to policymakers at all levels of government.

The Open House CD-ROM can be used in two ways. First, it can be accessed and explored from a standalone computer with a CD-ROM drive (preferably equipped with a sound card and speakers). Second, for those with computers with an Internet browser and connection, active Web links have been provided that will allow users to interact with many USGS Web sites. The CD-ROM is meant to be both entertaining and educational to a wide range of users and has been generally well received. The USGS general interest publications on the Open House CD-ROM are also on the Web as part of the Digital Library of the State of the

Environment, to be described next.

Building a digital library in the federal government seems like "Mission Impossible" these days since it, of course, has to be state-of-the-art, scalable, low maintenance, and support agency standards and universal access, but be done at little or no cost, right away, and with interagency partnerships. The "solution" by the author so far has been to (1) focus on the "best content" first; (2) author-once tools for the Web and CD-ROM; (3) repurposing and integrating; and (4) archiving and distribution on a series of Web-connected CD-ROMs. A Digital Library of the State of the Environment (see Appendix F) is in effect a "data warehouse" of publications, as described recently by Microsoft:

> *"Improved Decision Making with Better Data Access and Analysis: In the past, there was no central data access and analysts relied on manually compiling data from multiple sources. Data warehousing is a decision-support process involving a number of information technology components and services. It has become one of the most dynamic, interesting, and fast-growing segments of the information technology industry. More specifically, a data warehouse gathers operational data from single or multiple groups, and then stores it with time and history information to allow for effective decision support. It can provide multiple views of information to a spectrum of users. The power of this concept is that it provides users with access to trends analysis and with answers to business questions that are extracted from previously unrelated data sources, and it enables users to derive meaning from previously independent data. Data warehouses store data in static form, and then are configured and optimized to support complex decision support."*

B. A Sustainable Development CD-ROM Resource for the Southern Appalachian Area (SAA)

This CD-ROM resource, presented at the SAMAB 8th Annual Conference in November 1997, has been developed further to include a GIS Starter Kit the with LandView III mapping software and SAA databases selected by the SAMAB GIS Subcommittee for use in empowering SAA communities to learn and apply GIS and the SAA database to sustainable development activities. The SAA databases were exported from ArcInfo format and imported into a special 135 county version of LandView III with its national databases (see Appendix G).

Plans for the GIS Starter Kit for the Southern Appalachian Area include testing by a group of volunteers from the SAMAB organization and then use in an outreach effort to SAMAB communities that would like to begin to use GIS in their land use planning and sustainable development activities. The outreach effort could consist of a day-long training session at several convenient locations within the SAMAB region that have computer training facilities. At these sessions, community planners and activists with basic PC computer skills in using the Windows 3.x or 95 operating system and an interest in learning and applying GIS/desktop mapping software could be trained. In addition, those community planners and activists with their own local spatial databases could be shown how to import them into LandView III and make their own CD-ROM. This outreach experience should provide additional training exercises and data layers that could be added to LandView III for another round of CD-ROM distribution. This CD-ROM is also part of a larger effort in support of the U.S. Interagency Working Group on Sustainable Development Indicators and the President's Council on Sustainable Development National Town Meeting May 1999.

III. Some Next Steps

The EPA Region 3 and Chesapeake Bay Program are actively seeking partners to build a distributed decision support system on the Web and CD-ROM. The author has experience with using Chesapeake Bay databases for exploratory data analyses and visualizations using S-PLUS (see http://www.sdi.gov — List of All Infobases and S-Plus Statistical Analyses and Graphics on Environmental Data). The Chesapeake Information Management System (CIMS) (see http://www.chesapeakebay.net/) is an excellent opportunity for building a decision support system (services) using data mining and visualization and developing "drill down" type applications on the Web. For example, their Chart the Bay is an interactive, Web-based tool for visualizing and mapping Bay data, viewing and identifying features on a map, as well as downloading data and metadata.. Chart the Bay is a custom application written using Visual Basic (Microsoft) and MapObjects (ESRI) and the served by the mapObjects Internet Map Server (ESRI) (see http://www.chesapeakebay.net/bayprogram/data/gis/virtualmaps.html)

Another interesting decision support service is FedStats (see http://www.fedstats.gov) which is a new window on the wealth of statistical information available to the public from the Federal Government. Intended as a "one-stop" Web site for statistics collected and published by over 70 Federal agencies, the author is working with the FedStats Web site group to enhance the capabilities of the section on regional statistics so users can "drill down" from state to county and even to "microdata" that is integrated across agencies in such a way as to tell an interesting and useful story about the data. A prototype "drill down" Web application using socio-economic data from LandView III in a Folio infobase with a clickable map image interface has been developed (see http://www.sdi.gov/ and then New Links and MapStats for FedStats Prototype 2).

Finally, the SDI Group plans to support and in the National Town Meeting on Sustainable Development with learning sessions about the uses of sustainable development indicators. The SDI Group is chartered by the White House Office of Environmental Quality to advise it on matters involving sustainable development and coordinate its activities with the work of President's Council on Sustainable Development (PCSD). The SDI Group plans to revise and finalize the progress report on sustainable development indicators, further develop the SDI Web site, including fostering the dialogue on the linkages among national, regional, and community indicators, and to offer assistance to communities, states and regions developing sustainability indicators by making data used in other information efforts like the FGDC more accessible.

Acknowledgements

The author acknowledges the guidance and support of Mark Schaefer, Paul Dressler, Jerry McFaul, Bruce Molnia, Joe Macknis, David Berry, John Moeller, and Valerie Gregg in this work. The CD-ROMs produced would not have been possible without the efforts of Peter Gattuso, Jerry McFaul, and Frank Van Manen. The author also acknowledges the technical support receive from Folio Corporation, a Division of Open Market Corporation, for assistance in the use of it software products and John Williams and his staff at ProInfo, Inc., a Folio business partner, for assistance in producing the CD-ROMs.

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Appendix A — Greater Yellowstone Ecosystem Web-connected CD-ROM for Decision Support

http://cdserver.er.usgs.gov/gye.htm

Appendix B — LandView III: Environmental Mapping Software and Community 2020: HUD Community Planning Software

http://cdserver.er.usgs.gov/lviii.htm

Appendix C — Distributed Geographic Information (DGI) after Brandon Plewe, "So You Want to Build an Online GIS", GIS World, November 1997, pp. 58-60, and LandView III — FGDC Metadata Clearinghouse Status (June 25, 1998)

http://cdserver.er.usgs.gov/lvonline.htm
http://cdserver.er.usgs.gov/lv3fgdc.htm

Appendix D — Presentation at the Decision Support Systems for Land, Natural Resources and the Environment-Denver Workshop, February 18, by Brand Niemann

1. LandView III: Environmental Mapping Software
Handout: LandView III Fact Sheet, EPA November 1997
Demonstration: 11 CD-ROM set for federal regions and nation
Related URLs:
http://www.epa.gov/ceppo
EPA Chemical Emergency Preparedness and Prevention Office
http://www.epa.gov/swerops/bf/html-doc/lv3.htm
LandView III: A Tool For Community Brownfields Projects
http://www.census.gov/geo/www/tiger/
U.S. Bureau of the Census Tiger-LandView III CD-ROMs Ordering Information
http://www.RTK.NET:80/landview/
Download LandView III Mapping Program from RTK NET

Note: The 11 CD-ROM set is accessible on the Intranet from a CD-ROM juke box at the USGS-National Center.

2. Community 2020 Community Planning Software
Handout: Community 2020 Packet
Demonstration: 4 CD-ROM set for four regions of nation
Related URLs:

http://www.hud.gov/cpd/c2020sft.html
Community 2020 HUD Community Planning Software
http://www.ezec.gov
Community 2020 Map Library
http://www.caliper.com/c2data.htm
The Community 2020 Data Library
http://www.caliper.com/mapserv/default.htm
Caliper's Maptitude Web Mapper

3. Virtual Reality Tours and Science-based Fly Overs
Handout: This is the USGS CD-ROM.
Demonstrations:
1. Worlds, Inc./Circle of Fire Virtual Reality Tour of Old Faithful
2. Non-interactive Fly Overs of Greater Yellowstone Ecosystem and the Chesapeake Bay Watershed
3. Interactive Fly Overs of Greater Yellowstone Ecosystem and the Chesapeake Bay Watershed
4. PowerScene Video from Cambridge Research Associates
Related URLs:
http://www.worlds.com (not on Web anymore)
CD-ROM and http://cdserver.er.usgs.gov/gye.htm
CD-ROM and http://www.pci.on.ca/product/fly.html
No URL

4. Greater Yellowstone Ecosystem Web-connected CD-ROM for Decision Support
Handout: Web Page and CD-ROM contents
Display: Selected maps and graphics
Demonstrations:
Web site and Web-connected CD-ROM
Large image compression and delivery on the Web and CD-ROM using MrSID in cooperation with the Library of Congress Geography and Mapping Division
Related URLs:
http://cdserver.er.usgs.gov/gye.htm
http://lcWeb2.loc.gov/ammem/pmhtml/panhome.html

Appendix E — "The Best of the USGS" — Science for a Changing World: The 1998 USGS Open House Web-Connected CD-ROM

1. Infobases
Selected Web pages by Theme (with videos-237.0 MB) (73.0 MB)
Acid Rain and Our Nation's Capitol (2.0 MB)
Time-Series Animation Techniques for Visualizing Urban Growth (with videos) (12.6 MB)

The North American Breeding Bird Survey (260 KB)
Coasts in Crisis (Online Version) (2.2 MB)
This Dynamic Earth (4.4 MB)
Endangered Ecosystems of the United States: A Preliminary Assessment of Loss and Degradation (892 KB)
Earth Science Corps Volunteer Guide (2.8 MB)
Manual of Federal Geographic Data Products (904 KB)
Fossils, Rocks and Time (820 KB)
Geologic Time (1.0 MB)
Helping Your Child Learn Geography (in cooperation with the U.S. Department of Education) (1.2 MB)
Natural Gemstones (388 KB)
State of the Chesapeake Bay 1995 (1.1 MB)
Stream Gage Monitoring Program of the USGS (752 KB)
Touch the Bay!: An On-Line source of information about the Chesapeake Bay (with videos) (1.3 MB)
U.S. Geological Survey Yearbook Fiscal Year 1995 (videos on earlier CD-ROM) (6.0 MB)
Volcanoes of the United States (2.0 MB)
USGS General Interest Publications (54.0 MB):
Applications of GIS
Earth Science for Everyone
Elevations and Distances in the United States
Geographic Information Systems
Geology of the Harpers Ferry Quadrangle Virginia, Maryland and West Virginia
Glaciers: Clues to Our Future Climate?
Groundwater and the Rural Homeowner
The Interior of the Earth
Landforms of the United States
Looking for an Old Map
Our Changing Continent
The River and the Rocks
Topographic Mapping
Topographic Map Symbols
USGS Maps

Map viewers
DEM3D, DLGV32, and TerraServer (38.0 MB)
MrSID-wavelet compression of very large images (105.0 MB)
PCIFLY-interactive flyovers (35.4 MB)
Installs (50.2 MB)

Appendix F — Building a Digital Library of the State of the Environment

http://www.sdi.gov/diglib.htp

Appendix G — A GIS Starter Kit for the Southern Appalachian Area

http://www.sdi.gov/samab.htm

The Digital Earth: Understanding our planet in the 21st Century by Al Gore
http://www.opengis.org/info/pubaffairs/ALGORE.htm
The National Center for Environmental Decision making Research (NCEDR)
http://www.ncedr.org
WARMF Chen
NCGIA Workshop on Collaborative GIS
FGDC Pesachowitz
http://www.fgdc.gov/Org/Steer/steer042398.html
CBEP Clearinghouse for Sustainable Community Development
http://www.epa.gov/ecocommunity
Aurora Partnership-Meeting Notes/Handouts
Agricultural Databases for Decision Support (ADDS)
http://www.reeusda.gov/adds/

7/98 DRAFT
A Decision Support Resource CD-ROM for the Chesapeake Bay Ecosystem
Decision makers and stakeholders need a ready reference resource for the Chesapeake Bay Ecosystem when contemplating decisions. State-of-the-art Web-connected CD-ROM technology exists to create such a ready reference resource. The new U.S. EPA Center for Environmental Information and Statistics and U.S. EPA Region 3 have teamed to produce and maintain this ready reference resource using author-once techniques for Web, CD-ROM, and print distribution. This work would build on the previous experience with producing resource CD-ROMs for the Chesapeake Bay Program (Niemann and Macknis, 1994) and the U.S. Geological Survey (Open House, April 1998). This work will identify gaps in data and information and ways to improve the presentation of the data and information for users that can be incorporated in the next version. A proposal has recently been submitted to the CBP Monitoring Subcommittee; it is entitled "Application of New S-PLUS Software Tools for Exploratory Data Analysis and Display of Possible Multivariate and Nonlinear Relationships Between Various Monitoring and Modeling Databases." (See attached.) The previous CD-ROM and Folio-S-PLUS work for the Chesapeake Bay Program is available at http://198.183.146.250/cgi-bin/om_isapi.dll?clientID=2223&infobase=SPLUS41.NFO&softpage=Browse_Frame_Pg

The initial contents of this CD-ROM resource for user evaluation would be:

1. Chesapeake Bay Web Pages — captured from the Site Map (http://www.chesapeakebay.net/bayprogram/search.htm) and repurposed (have done level = 1 and binary files)
2. Other captured and repurposed documents like the 1995 State of the Bay, Guide to Water Quality Monitoring Data, etc.
3. The processed data sets from the Data Hub including water quality, living resources, modeling, GIS, etc.
4. Excel versions of the processed data sets with the Excel Viewers. (Note: The Excel versions are used for the S-PLUS analyses and displays.)
5. S-PLUS analyses and displays organized in PowerPoint presentations with the PowerPoint Viewers.
6. LandView III for the watershed area with selected processed data sets included.
7. Large images compressed and viewed with MrSID like the USGS watershed Landsat composite image.
8. Flyovers (interactive and non-interactive) and video clips available from the USGS Open House CD-ROM.
9. Other Web pages, documents, and databases that are identified during the process.

Suggested Schedule

Develop a prototype CD-ROM during July and August for demonstration and discussion in September.

Develop the first review release by December for evaluation.

Attachment Comments:

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CASE STUDIES

Technology-Assisted Decision Support: The Famine Early Warning System for Africa

Leonard Gaydos, Stephen Howard, and James Verdin

Abstract

The Famine Early Warning System (FEWS) has helped the U.S. Agency for International Development, the United Nations, national ministries, and relief and humanitarian organizations prevent famine in 22 nations of sub-Saharan Africa since 1985. FEWS analysts provide expert analysis of socioeconomic and agrophysical data in order to monitor food security and identify populations at risk of starvation and malnutrition.

Satellite-derived weather and vegetation index images are supplied by The National Oceanic and Atmospheric Administration and NASA every 10 days. The U.S. Geological Survey EROS Data Center serves as the system's long-term data archive and helps FEWS analysts in the U.S. and host countries integrate these data for use in monitoring and modeling crop potential. Although trends noted in vegetation index images have provided the most important predictors of future crop potential, continued technical developments relying on meteorological remote sensing and modeling data are also making timely assessments possible. The long-term archive of data and a clearer understanding of the relationships of important variables can be used to improve models, leading to better assessments with longer lead times for appraising the need for food relief.

I. Preventing Famine

Droughts south of the Sahara Desert in 1973-74 and again in 1984 brought famine to the Sahel region of Africa. U.S. and international aid organizations responded with food assistance. To help Sahelian countries understand the dynamics of food security and to provide as much advance warning of potential famines as possible, the U.S. Agency for International Development (USAID) established the Famine Early Warning System (FEWS) in 1985. Partners include NASA, the National Oceanic and Atmospheric Administration (NOAA), the U.S. Geological Survey (USGS), and Associates in Rural Development (ARD), the prime contractor. FEWS has grown into a technology-assisted decision support system that is helping reduce the loss of life caused by lack of access to food. FEWS' focus is drought; however, FEWS analysts provide country background information during floods or conflict-induced food emergencies as well.

FEWS now includes 22 countries across the Sahel and in eastern and southern Africa. Field representatives in participating countries collect data on crops, markets, population, and other socioeconomic indicators. They also monitor local and regional conditions, using satellite images and analyses to estimate current and near-future conditions. These images are supplied by NOAA and NASA and made available by the USGS through the Africa Data Dissemination Service (ADDS), an information source on the Internet (http://edcintl.cr.usgs.gov/adds/adds.html). Analyses of all the relevant data are conducted in the field and in Washington D.C. by the ARD staff of agricultural specialists and Africa experts.

II. Operation of FEWS

The FEWS analytical framework is based on a conceptual model of household behavior that seeks to conserve resources. This approach which has proved to be a good model for actual behavior during times of stress, considers coping strategies such as behavioral adaptation, selling of assets, and migration. These individual family decisions are assumed to be reflected in available secondary data.

Rather than being national in scope, like previous efforts, FEWS is both subnational and regional. Field representatives compile and analyze data on a provincial and district level to determine specific populations at risk. These representatives report to USAID on a nation-by-nation basis, but the resulting monthly FEWS Bulletin provides a geographically specific view of famine risk for the entire region (http://www.info.usaid.gov/fews/fewspub.html#Bulletin).

The most current and synoptic data for FEWS come from satellites, with collection and processing by NOAA and NASA. Normalized Difference Vegetation Index (NDVI) images are supplied every 10 days by NASA. These images are a measure of photosynthetic activity and can be compared temporally to track crop growth. With data archived starting in 1982, scientists can compare current conditions and trends with the historical record, increasing the predictive power of the data.

NOAA supplies rainfall estimate images derived from a variety of sources, including a rainfall-gauging network, satellite images, and models that account for wind, relative humidity, and topography. These data are also supplied every 10 days for analysis. The USGS maintains, on the World Wide Web, all the satellite and digital map data, such as administrative boundaries, agroclimatic zones, cropland use intensity, elevation, and roads. The ADDS provides public access to all the FEWS data archived since the inception of the project. Additionally, the USGS has developed a suite of PC-based data managers (also available from the ADDS) to help the FEWS field staff analyze the various types of data (rainfall, agriculture, prices, and satellite data). Recently, USGS has implemented a "crop water satisfaction index," which evaluates crop water needs against the available water supply. The index, developed by the Food and Agriculture Organization of the United Nations, has been shown to be highly correlated to crop yields. Field representatives now have an additional tool to help estimate crop conditions. The NDVI indicates current crop conditions, whereas the rainfall data and the crop water satisfaction index can indicate crop conditions in coming weeks. USGS research into the effects of historical El Niño events affecting southern Africa provided early insight into possible similar effects for the 1997-98 event.

III. Decisions Supported by Technology

FEWS is an excellent example of a technology-assisted decision support system. Technology in the form of digital maps and images and specialized processing is supplied to the FEWS Washington staff and field representatives who make the final decisions on what the data foretell about human vulnerability to food shortages. As technology improves and people gain experience with assessing and forecasting conditions, fewer human lives will be lost to famine, thus achieving the central goal of FEWS.

Overview of Department of Defense Subsurface Modeling Tools

J.P. Holland and D.R. Richards

Abstract

The U.S. Army Engineer Waterways Experiment Station leads a consortium of U.S. Army, Navy, Air Force, Department of Energy (DOE), Environmental Protection Agency (EPA), and academic researchers in the development of the Groundwater Modeling System (GMS). The GMS is an aid for site characterization, for assessing the risk of contaminant exposure to ecological and human populations, and for evaluation of the efficacy of remedial and wellhead protection actions associated with contaminated groundwater resources at Department of Defense installations and other federal sites. The system is modular and operates across a variety of computing platforms. The GMS provides full connectivity to multiple subsurface flow and transport models (including MODFLOW and an enhanced version of MT3D), visualization, animation, geographic information system constructs, and parameter estimation within a single, consistent user environment. A number of research initiatives related to characterization of the impacts of subsurface heterogeneities on remedial effectiveness, mathematical description of flow and transport processes for military-unique contaminants, simulation of remedial alternatives, and computational efficiency on multiple computing platforms, are ongoing that are producing new modeling tools. These new system components will continue to be implemented in the GMS through 2001. The capabilities and future development path of the GMS are overviewed in general. Specific system capabilities associated with MODFLOW and MT3D are highlighted.

I. Introduction

The effective use of advanced modeling and simulation technology is an integral component of all facets of Department of Defense (DoD) readiness, modernization, and tactical superiority. This is of vital importance in DoD's environmental restoration and stewardship activities, wherein DoD has responsibility for the cleanup of almost 9,000 contaminated sites on its active installations. In support of environmental management objectives, the U.S. Army Engineer Waterways Experiment Station (WES), as the DoD lead in the research and development of environmental quality modeling and simulation (EQM) technology, leads a consortium of DoD, DOE, EPA, and academic researchers in the development of the DoD Groundwater Modeling System (GMS). Collaboration with other researchers, such as those within the U.S. Geological Survey (USGS), further extends the capabilities of the GMS. The GMS provides a single, comprehensive means for DoD to use advanced environmental quality modeling and simulation assets in site characterization, contaminant transport/fate assessment, and in the evaluation of differing remedial action strategies at DoD installations. The system also has high dual-use capabilities as exemplified by its application for salinity intrusion, wellhead protection, and dredged material facility design.

Increased productivity in the use of subsurface modeling and simulation by cleanup specialists, ranging from 50% to 75%, can be achieved from use of the GMS. For example, setup for a given subsurface model can now be accomplished in hours, rather than days or weeks, via the GMS. This empowers cleanup specialists to efficiently evaluate many more scenarios (e.g., differing site hydrogeologic conditions and remediation alternatives) than possible previously. This, in turn, increases DoD and regulatory confidence in site-specific remedial designs. For example, WES and the U.S. Army Environmental Center have used the GMS to design a pump-and-treat system for Schofield Army Barracks, HI. The use of GMS modeling technology to rigorously consider site characterization uncertainty, and to present modeling results in a manner amenable to regulators, resulted in regulatory acceptance of a lower-cost remedial system that is technically equal to more expensive proposed systems. Cost savings from this one application were estimated to range from $7.5M to $10.0M. Based on experience in industrial and military cleanups, between 10% and 20% of characterization and remediation costs can be saved through the use of the GMS technologies at many cleanup sites. This could result in cleanup cost reductions in the billions of dollars within DoD alone. Extension of these savings to DOE sites could easily be an order of magnitude larger.

II. System Features

Flexibility and portability are prime design considerations for the GMS. The DoD groundwater modeling user community is known to compute on personal computers (PCs), UNIX workstations, and supercomputers. Version 2.1 of the GMS provides for application of six subsurface models (FEMWATER, MT3D, MODFLOW, MODPATH, RT3D, and SEEP2D). Six additional models (NUFT3D, PARFLOW, SEAM3D, ADH, UTCHEM, and OS3D) are being incorporated within the GMS at present. The ability to model surface water — groundwater interactions is undergoing verification and will be fielded in 1998 as well. Note that the aforementioned models represent joint developments between the research consortium partners.

The GMS has been designed specifically to aid multi-disciplinary users in the evaluation, design, and operation of differing subsurface remediation methods (ranging from traditional pump and treat to bioremediation to natural attenuation) for site-specific hydrogeologic conditions. This design objective is the primary criterion governing the selection of the models listed above for integration into the GMS. The system has state-of-the-art visualization (for both two and three-dimensional data), animation (through the AVI video file format), grid generation, conceptualization and parameterization capabilities on-board that access modeling results directly without external software requirements. The GMS runs seamlessly, and with the same look and feel (developed through a WES-Brigham Young University [BYU] collaboration), on UNIX workstations, personal computers running Windows 3.1, 95, and NT, and supercomputers. In this manner, users become acquainted with only a single computational environment in their use of multiple modeling and analysis tools, thereby adding yet another level of increased personal productivity. The GMS's modules allow components of the system to be used in the field by site characterization technologists, in the workroom and/or laboratory by remedial designers, and in the conference room by project managers for presentation of highly technical data to decision makers.

GMS v2.1 has numerous tools to support site characterization. Data from wells, boreholes, and cone penetrometer tools, including the multi-agency Site Characterization and Penetrometer System, can be seamlessly imported into the GMS. An extensive geostatistical library is integrated into the system and includes **kriging** (ordinary and universal), inverse distance weighting, natural neighbor, and Clough-Tocher techniques. A vastly expanded set of site characterization capabilities, including new geostatistical interpretative methods and inverse modeling techniques, will be available within the GMS in 1999.

A key component of the system, the Map Module (also a joint WES-BYU development), increases the productivity of subsurface conceptualization, flow/transport modeling, and remedial design simulation by over a factor of 10. This is accomplished through the GMS's use of standardized geographic information system (GIS) constructs (e.g., arcs, polygons, points, objects, etc.) which empower the direct import and export of existing data within digital elevation, hydroenvironmental, and installation management databases directly and rapidly. The Map Module also empowers graphical assignment of initial and boundary conditions, and site conceptual features (such as rivers, land cover, material properties, subsurface stratigraphy, lakes, etc.). Further, the Map Module effectively decouples the selection of numerical model and site conceptual model development, thereby allowing the use of the best, or several, subsurface models for a given site without requirements for redeveloping the site conceptual model.

Both finite difference and finite element grid generation tools are resident within the GMS for both structured and unstructured grids (Figure 1). In addition, grids developed external to the GMS can be imported within the system. The system also has a series of new calibration tools that enhance the parameterization and calibration of a GMS-supported subsurface model for a given site implementation. The desktop of the GMS, with a contaminant plume from an U.S. military installation visualized, is shown in Figure 2.

A. GMS-Supported Features For MODFLOW, MODPATH, AND MT3D

GMS v2.1 supports the following MODFLOW packages:

- Basic package
- Output control
- Block-centered flow
- Well, Drain, Stream, and River
- Evapotranspiration
- General head

- Recharge
- Multiple solvers (SIP, SSOR, and PCG2)
- Horizontal flow barrier
- Time-varying head

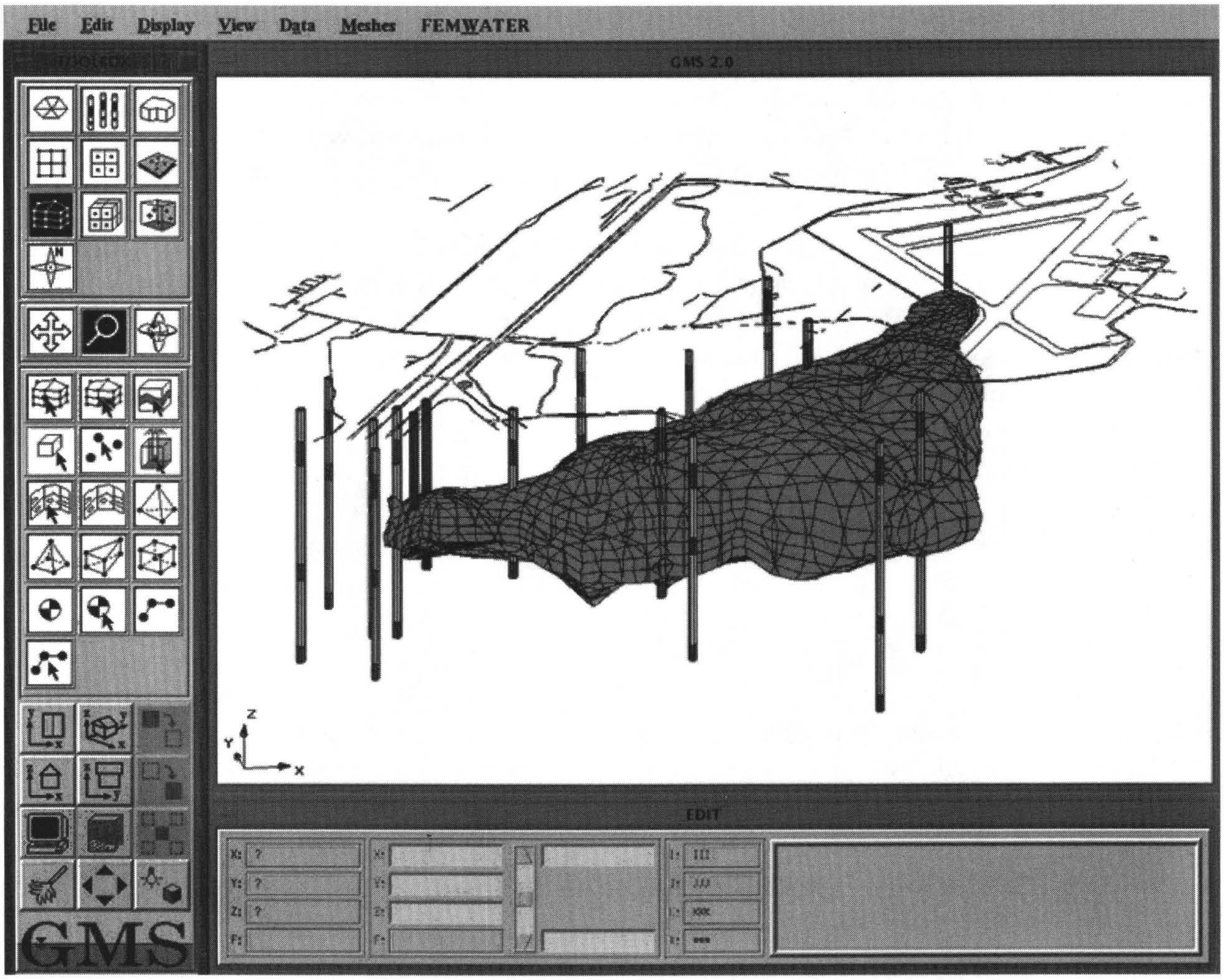

Figure 1. Unstructured GMS Grid of Military Cleanup Site.

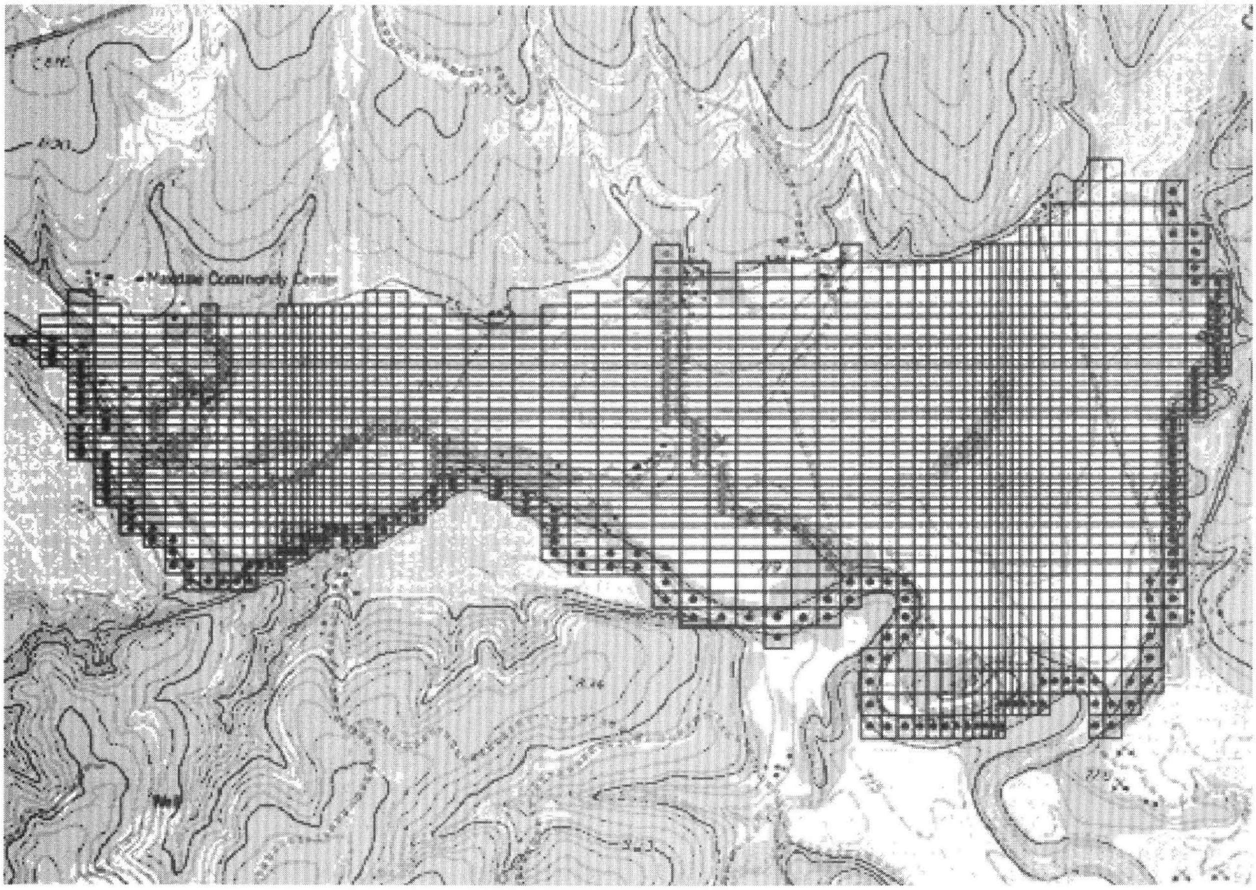

Figure 2. GMS desktop with visualization of a contaminant plume and associated wellfield.

All general MODPATH options are supported. A GMS-developed MODFLOW grid, draped over a USGS quad sheet of a specific contaminated aquifer site, is shown in Figure 3.

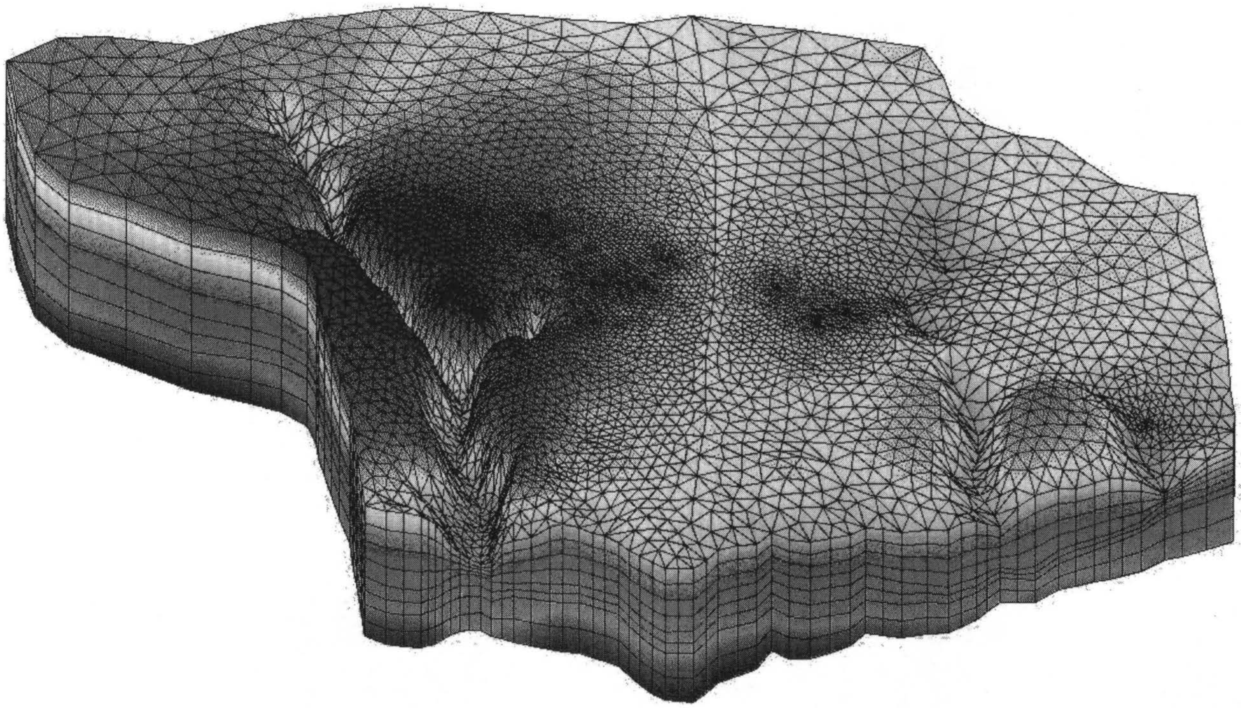

Figure 3. A MODFLOW finite difference model automatically constructed from a site-specific conceptual model.

GMS v2.1 supports MT3D v1.5 and its following packages:

- Basic transport
- Advection and dispersion
- Source/sink mixing
- Chemical reactions

Multiple chemical species transport capabilities within MT3D are also being supported. In addition, RT3D, which utilizes the transport functionality of MT3D to conduct biodegradation calculations, is also supported within GMS v2.1 with the following pre-defined reactions: (a) none (tracer transport); (b) instantaneous aerobic degradation of hydrocarbon (BTEX) contaminants; (c) kinetic-limited degradation of BTEX with multiple electron acceptors; and sequential decay reactions. User-defined reactions can be entered as well.

B. GMS Remedial Simulators

The GMS has been specifically developed to support DoD (and other agency) environmental restoration activities related to contaminated groundwater resources. This driving force underscores the reason for the selection of the models scheduled for inclusion in the GMS: each has a unique capability for modeling a particular set or subset of remediation technologies. Listed below is the current schedule for fielding direct simulation capabilities for specific remediation technologies. Note that this schedule is based on a number of factors including the availability of funds, the state of treatment technologies at the time of simulator development, and assumption of achieving a level of confidence in simulating a given cleanup technology. Also note that multiple dates are listed for certain technologies representing the presence of existing capabilities within GMS and planned future additions.

- Pump & Treat, Hydraulic Barriers - FY97
- Steam Injection / Vapor Ext., Electrical Heat. - FY98
- Natural Attenuation for Explosives - FY98, 00
- Bioremediation for Fuels, Solvents, Explosives - FY97 - 99
- Surfactant-Enhanced Remediation - FY99 - 00
- Bioventing, Soil Vapor Extraction - FY98 - 99
- Air Sparging - FY99
- Multi-Component Simulation - FY99 - 00
- In-Situ Chem. Simulator - FY99 - 00
- Electrokinetics - FY99 - 01

III. GMS Implementation in Networked Computational Environments

Many of the hydroenvironmental challenges facing cleanup specialists will require computational sophistication orders of magnitude beyond the current state of practice. As such, these problems will require the capabilities of high performance computing (HPC) resources. Additionally, these HPC resources must appear as extensions of the local user's desktop to facilitate their effective use across networked environments (e.g., the World Wide Web). The DoD, through its HPC Modernization Program (HPCMP), is placing the best of vector and scalable parallel computing resources in the hands of its users. One of the major efforts under the HPCMP, the Common High Performance Computing Software Support Initiative, is providing WES with the opportunity to greatly enhance the productivity and efficiency of the GMS on networked, scalable architectures while maintaining current GMS capabilities on PCs and workstations.

Flexibility and portability are key aspects of WES's scalable GMS development. This is due, in large part, to the diversity of the HPC resources available within DoD. WES has targeted the following HPC architectures for implementation of the GMS: Cray T3E, IBM SP, and the SGI Origin 2000. Given this breadth of architectures, and the desire to maintain an optimum amount of model code for both scalable and single-processor machines, WES adopted a scalable algorithm development paradigm centered on the use of:

- FORTRAN 77, 90, and C languages
- Message passing via MPI with single program, multiple data constructs
- Grid partitioning with each processing element (pe) owning a portion of the numerical domain

- Use of ghost nodes, where nodes of a given element are owned by different pe's
- Load balancing, using software tools such as METIS from the Army High Performance Computing Research Center
- Use of pre- and post-processing to augment smooth model execution on the scalable HPC machines. General model setup, however, remains within the GMS

In addition, we wish for model executions to be launched from the modeling systems discussed above, and for post-processing to be conducted there as well. WES is currently collaborating with the University of Texas-Austin and Syracuse University (under the auspices of the Programming Environments and Training component of the HPCMP) to field a Web-based version of the GMS (Figure 4) for use on problems of extreme scale and sophistication. This version of the GMS will also greatly facilitate access to physical, biochemical, and toxicity databases that are resident on remote, networked servers, and would augment collaborative sharing of data and modeling results. These GMS capabilities will be implemented starting in 1999 and continuing through 2001.

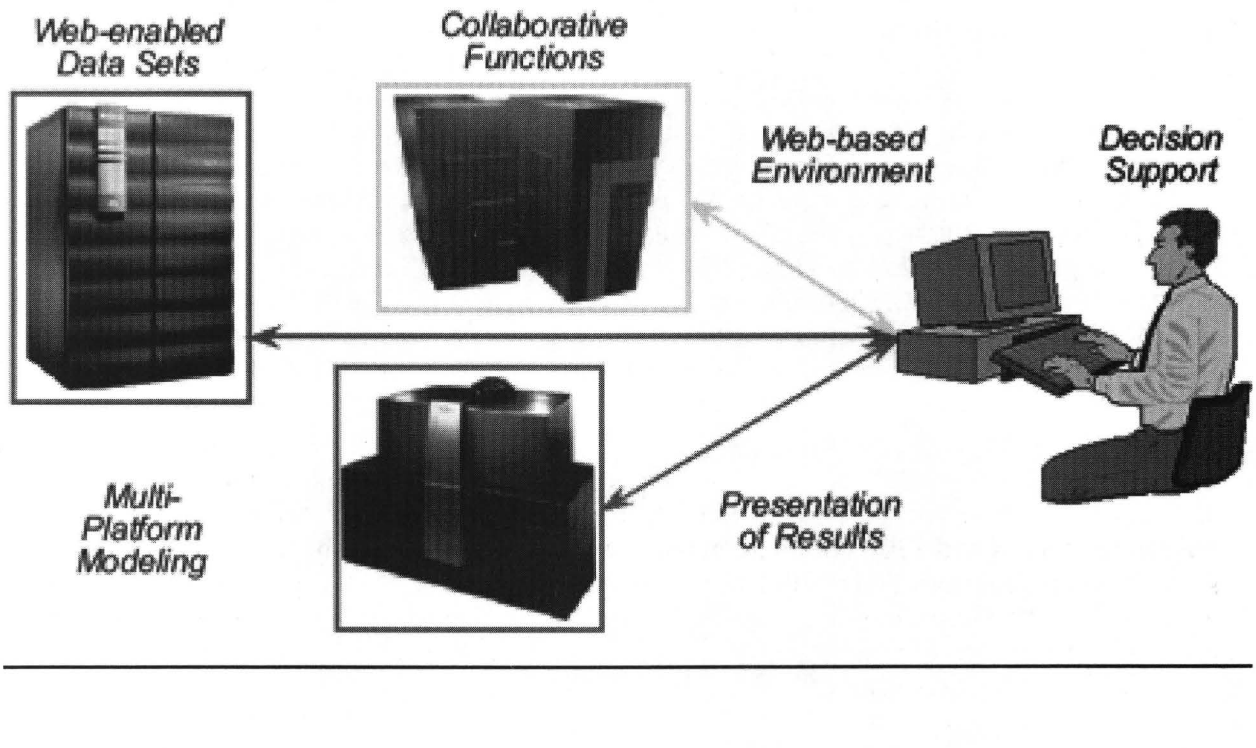

Figure 4. Conceptual schematic of web-based GMS.

IV. GMS Development Path

Synopsized in the table below is the planned GMS development. This development path is specifically developed to produce coupled EQM systems in support of DoD environmental quality management that provide an ever-increasing level of computational and scientific sophistication. The development path also includes the integration of components of three of WES's hydroenvironmental modeling systems: the GMS, the Watershed Modeling System, and the Surface Water Modeling System. The reader is referred to the WES hydroenvironmental modeling Web site, http://chl.wes.army.mil/software for details and demonstrations of these individual systems. Note, however, that these systems will be linked in a Web-based framework, with linkages to remote databases and differing computational assets, as described above.

M&S System Capability	Deliverable Dates
Addition of optimal remedial design modules for ten to fifteen technologies, with optimization, to the GMS.	FY98-01
Integration of watershed and groundwater modeling tools within the GMS and Watershed Modeling System.	FY98-99
Coupling of surface water and groundwater modeling tools for multi-scale phenomena. Integration of tools under a comprehensive modeling environment (CME).	FY99-00
Integrated surface water - groundwater - watershed investigations empowered across a heterogeneous, networked environment.	FY99-01
Full ecosystem modeling and simulation under CME with risk and uncertainty for both human and ecological receptors.	FY00-02

V. Summary

The Department of Defense has at its disposal an excellent cadre of modeling and simulation technology, typified by the Groundwater Modeling System, in support of hydroenvironmental analysis and decision support. The effective use of this technology, by over 600 Federal government users and 1300 commercial users worldwide, has been shown to result in significant cost savings, and results in more timely acceptance of DoD activities by regulatory agencies. The environmental quality modeling and simulation challenges of the future will require significant technical gaps to be overcome. These gaps are both scientific (e.g., modeling subsurface hydrogeologic and biogeochemical heterogeneity effectively in engineering-scale continuum models) and institutional (e.g., lack of regulatory or management acceptance of modeling and simulation results, especially for innovative cleanup technologies). These gaps, however, can be overcome in part through the conduct of focused research investigations planned and executed by the DoD services and its technical partners (e.g., DOE, EPA, USGS, academia). Dedicated, in-house user support for the GMS and its analogous watershed and surface water systems will greatly enhance the effective implementation of these technologies in environmental restoration and stewardship.

Acknowledgement

This paper was prepared from research and development conducted by the U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. Permission was granted by the Chief of Engineers to publish this information.

The Southern Appalachian Assessment Geographic Information System (GIS)

Karl A. Hermann

Abstract

The Southern Appalachian Assessment (SAA), conducted from November 1994 through April 1996, relied heavily on geographic information system (GIS) technology and information. The multi-agency effort presented a challenge to cooperators on how to effectively work together in achieving the goals and objectives of the assessment within the constraint of a tight timeline. This paper focuses on how the GIS component of the SAA met that challenge, with respect to the organization, development, and implementation of an interagency GIS.

In October, 1994, the cooperating partners of the multi-agency Southern Appalachian Man and the Biosphere Program (SAMAB) decided to collaborate on an assessment of the status and condition of the ecological resources in the Southern Appalachian Region. In addition, the regional assessment was to identify and prioritize areas in need of additional protection or ecological restoration. SAMAB is a consortium of federal and state agencies working in partnership to promote ecosystem management and sustainable development in Southern Appalachia. The membership includes: the National Biological Service, the US Forest Service, the US Environmental Protection Agency, the Tennessee Valley Authority, the National Park Service, the US Fish and Wildlife Service, the US Geological Survey, the Department of Energy's Oak Ridge National Laboratory, the Army Corps of Engineers, the Appalachian Regional Commission, the Economic Development Administration, and the States of Tennessee, Georgia, and North Carolina.

It was recognized early in the SAA planning stage that GIS technology and information would play a vital role in the assessment and reporting processes. Thus the primary objective of the SAA GIS was to coordinate and provide the SAA cooperators with an appropriate multi-agency GIS infrastructure and analytical support in the multi-team organization of the assessment project. The GIS effort included the identification, compilation, integration, and analysis of ecological and supporting data for the assessment activities. The effort also included providing the cooperators, other researchers, and the public with appropriate access to the information. Given that there were no proven designs or true success stories for multi-agency regional ecological assessments, the processes and accomplishments of the SAA and its GIS component are important for other potential multi-agency efforts to consider.

I. Introduction

The Southern Appalachian Assessment (SAA), conducted from November 1994 through April 1996, relied heavily on geographic information system (GIS) technology and information. The multi-agency effort presented a challenge to cooperators on how to effectively work together in achieving the goals and objectives of the assessment within the constraint of a tight timeline. The effort to organize, develop, and implement an interagency GIS to support the SAA was a large undertaking. While the effort was called a success, it was not without problems and personal sacrifice.

In October 1994, the cooperating partners of the multi-agency Southern Appalachian Man and the Biosphere Program (SAMAB) decided to collaborate on an assessment of the status and condition of the ecological resources in the Southern Appalachian Region. In addition, the regional assessment was to identify and prioritize areas in need of additional protection or ecological restoration. The study area was defined as the Southern Appalachian Mountains, ridges and valleys from the Northern tip of Virginia well into Alabama. The area, defined with county boundaries, encompasses seven states in its 37.5 million acres.

SAMAB is a consortium of federal and state agencies working in partnership to promote ecosystem management and sustainable development in Southern Appalachia. The membership includes: the National Biological Service, the U.S. Forest Service, the U.S. Environmental Protection Agency, the Tennessee Valley Authority, the National Park Service, the U.S. Fish and Wildlife Service, the U.S. Geological Survey, the Department of Energy's Oak Ridge National Laboratory, the Army Corps of Engineers, the Appalachian Regional Commission, the Economic Development Administration, and the States of Tennessee, Georgia, and North Carolina. The Natural Resources Conservation Service joined the cooperative in February 1996.

II. SAA GIS Objectives

The primary objective of the SAA GIS was to coordinate and provide the SAA cooperators with an appropriate multi-agency GIS infrastructure and analytical support in the multi-team organization of the assessment project. It was recognized early in the SAA planning stage that GIS technology and information would play a vital role in the assessment and reporting processes. In fact, GIS became one of the primary assessment tools. Thus the success of the SAA GIS component was critical to the success of the overall assessment.

The GIS effort included the identification, compilation, integration, and analysis of ecological and supporting data for the assessment activities. The effort also included providing the cooperators, other researchers, and the public with appropriate access to the information. Given that there were no proven designs or true success stories for multi-agency regional ecological assessments, the processes and accomplishments of the SAA and its GIS component are important for other potential multi-agency efforts to consider.

III. Organization

The SAA GIS was a non-centralized organization. There were twelve GIS operation sites coordinated through one site. The sites represented the active participation of the National Biological Service, the U.S. Forest Service, the Environmental Protection Agency, the Tennessee Valley Authority, the National Park Service, U.S. Geological Survey, and the Bureau of Land Management. The organization idea was to place data and GIS analytical expertise and support closest to the scientists. This style of organization had advantages in that it aligned GIS support directly with the other organizational components of the SAA, but it also proved difficult in terms of coordination. However, given any project with more than 150 active participants at dozens of locations in different agencies, coordination is a challenge.

The overall assessment organization included the four main resource teams of atmospheric, aquatic, terrestrial, and social, economic, and cultural. Both the terrestrial and social, economic, and cultural teams were subdivided into specialty areas. The terrestrial team had a forest health sub-team and a plant and animal sub-team. The social, economic, and cultural team was divided into a human dimensions sub-team, a recreation sub-team, a forest products sub-team, and a roadless/wilderness subteam. In addition to the resource teams, there was a policy and oversight team, a report writing team, a public involvement team, an integration team, and the GIS/data base team.

The GIS team determined a liaison person for each of the teams or sub-teams. These individuals were thus members of two teams, the GIS team and their assigned team. Their responsibility was to assist in determining the GIS data and resource needs that the resource team required in their assessment effort. The liaisons were also responsible for monitoring the development of the required data sets for their resource team and determining critical timelines. They also coordinated production of the team's GIS graphics for the technical and summary reports. ARCView training was provided to SAA scientists so that they could employ GIS directly in their research. Several SAA scientists became very competent on the use of ARCView and it played an important part in their analysis. Assignments were also made among the GIS team on responsibilities for data set development. That responsibility included source data acquisition, data conversion, enhancements to the desired use requirements, quality assurance, and metadata documentation. Hundreds of data sets were developed and processed during the course of the assessment.

The interaction among the GIS team members was accomplished in several ways. There were some face to face meetings early on in the effort, only one of which had the bulk of the GIS participants in a attendance. Regular team-wide communication contact was accomplished via weekly conference calls and team-wide e-mails. Next day mailings were frequent, especially towards the end of the project, as timelines became more critical. Finally, the one-on-one phone communication or face to face encounters at other resource group team meetings were important types of GIS team interactions.

There were problems with the GIS team organization and participation. These problems were largely due to the differences in how different agencies operate and handle their work assignments. However, some of the problems were common to any project. These include personality conflicts, opinion differences, varying skill levels, and time management.

IV. Information Needs Assessment

The effort to identify the information needs of the assessment scientists proved to be difficult. The resource teams were being organized at the same time that the GIS team was trying to determine what data sets to compile for whom and when. Furthermore, very few of the scientists had ever worked on a regional assessment prior to the SAA. Many of the scientists were still learning how to conduct their team's business, so a classical user needs assessment fell short of what was required. The understanding of what the SAA scientists needed was primarily gained through an interactive dialog of GIS members stating what was available and the scientists voicing their developing understanding of what they could do in the assessment.

Some data needs were intuitive and quickly identified. These included, among others, land cover for the SAA and the state heritage program data.

V. Data Base Development

One enormous advantage in the data base compilation process was the fact that all of the cooperators active in the SAA used ARC/INFO. An early version problem was encountered, since the U.S. EPA site was still operating version 6.1.1. However, EPA moved to version 7.0.3 and we became fully compatible among the agencies. Thus, all data were converted into a ARC/INFO data base compatible with the other users. The data base had a standard projection and coordinate system. Since the study area spanned two UTM zones, a decision was made to define a unique SAA projection and coordinate system. The definition was a localized Albers Equal Area Conic projection employing the North American Datum of 1983 (NAD83).

The desire to share data with the agencies and the public drove the objective to use publicly available data as much as possible. It was an overall SAA objective to use existing data in the assessment. Therefore, the data base development effort largely consisted of converting existing data into ARC/INFO with the standard projection. Two examples of the data base development were the classification of land cover and the conversion of USGS digital line graph (DLG) data to ARC with additional attributes. The land cover classification effort, performed by Pacific Meridian Resources, Inc. under contract, was the largest of the data set compilation efforts. The data set, derived from Landsat Thematic Mapper data, was classified into 16 land cover types with a two acre minimum mapping unit. Traffic count attributes were assigned to the ARC version of the 1:100,000 USGS DLG class 1 and class 2 road segments. That information allowed for some of the modeling efforts to characterize road corridors. Data was complied at several scales. These include 1:2,000,000, 1:250,000, 1:100,000, and 1:24,000. The 1:100,000 scale proved to be the focus of much of the data analysis. Data layer themes included the following:

Administrative Boundaries
Reference Boundaries
Hydrography
Transportation
Topography
Land Cover Classifications
Ecological Classifications
Soils
Demography
Cultural and Historic Sites
Economics
Species Occurrence and Distribution
Potential Habitat
Air Quality — Monitoring and Models
Climate
Resource Monitoring
Pollution Sources Sites
Pollution Monitoring Sites
Pest Occurrence
Fire Occurrence

Anonymous ftp sites, to which anyone could write, proved to be very important in coverage and file exchange. However, the poor Internet accessibility of the US Forest Service required that tape media be exchange via next day mailings.

The data sets that were complied were sent onto the coordination site where the master data base was complied. As the master data base was complied, 8mm tapes were produced and distributed. Additionally, two separate beta versions of the data base (SAA version 1.0 and SAA version 2.0) were written onto CD-ROMs at the US Forest Service site in Columbia, SC. These CD-ROMs were individually written so the number of CDs that were distributed was small. The major product of the data base development effort was the publication of version 3.0 of the data base. Approximately 1,000 copies of the SAA GIS CD-ROM set were published in March, 1996. The SAA GIS data base CD-ROM set consists of five CD-ROMs. The set is being distributed to libraries, among the participant agencies, and the public on a first come, first serve basis. As of this date, no decision has been made about additional publication copies being produced, however, it is possible that some number of additional copies will be made available on a cost recovery basis.

The metadata documentation of the published CD-ROM set was far from being at the optimal state of release. However, the improved metadata and data sets are accessible through the SAMAB Southern Appalachian Home Page at: http://sunsite.utk.edu/samab. The SAA summary and technical reports are also retrievable from the SAMAB home page.

VI. Assessment Support

The SAA GIS team members provided valuable analytical support to the assessment. Often this was performed in collaboration with particular resource team members. Landscape analysis for potential habitat models and recreation based settings was an important example of the SAA GIS contribution. Analysis of the element of occurrence record (EOR) data, containing information on threatened and endangered species, was performed at only one GIS operation site. This was primarily done in order to limit access to the detailed data, which was provided by the state heritage programs with the understanding that the detailed locational level of data was to remain confidential. The reporting support was initially underestimated. Hundreds of graphics were produced for the technical and summary reports. Standards could have been improved; however, even the basic standards were not always followed through by some GIS team members. Towards the end of the project a great deal of extra effort was required to put GIS graphic projects into a more acceptable form. One of the original concepts of scientists producing their own final version graphics in ARCView fell short from a quality standpoint.

VII. Conclusions

The SAA GIS made a vital contribution to the Southern Appalachian Assessment. GIS graphics and analytical results are a major part of the summary and technical reports. The SAA GIS Data Base CD-ROM set is an important contribution for future analysis by the agencies, special interest groups, and the public. The information represents a huge savings to others who might have otherwise attempted to compile similar data sets. In terms of what was accomplished, the SAA GIS was a success. The operations could have been improved; however, a foundation for future cooperation among agencies in the region has been well established. While the current level of cooperation is not perfect, it is at least occurring to a degree within the region.

DEMONSTRATION ABSTRACTS

A Biological Decision Support System (BDSS) for Human Land Use Impact Assessment: A Pilot Project for Teton County, Wyoming

Patrick Crist

Introduction

In FY 1997, the USGS/ BRD Gap Analysis Program and University of Wyoming Spatial Data Visualization Center were awarded a state partnership grant to produce a state bioinformation node and to develop a decision support system for the use of biological data by county land use planners. This BDSS has two intended goals: (1) to provide an early warning system of potential conflict between proposed human land uses and biotic resources prior to investment in unsuitable projects, or to aid the identification of mitigating features that will allow for less contentious project approval; and (2) to create a categorization system that is generalizable to any land tract, land use, and biotic element (plant community or animal species). A primary feature of the system is that it does not require knowledge of GIS or biology to operate it.

This system takes an individual element (animal species or plant community) and land tract approach which is different than traditional local government approaches of identifying "critical habitat areas" (Hallock, 1986) which should not be confused with designated critical habitat as used in the endangered species act. Counter to a "single species focus" the system is meant to consider ALL species equally while providing the ability to filter results for legally protected species only.

I. Description

The BDSS is composed of: a PC computer platform, GIS software with a custom interface (ArcView 3), and data (GAP and other local data). Because no knowledge of GIS or biology is assumed on the part of the user, the system uses an *a priori* approach that categorizes potential levels of impact by human uses on biota. This requires that each land use be "cross linked" to a simplified scheme of five impact levels of physical land cover disturbance and four impact levels of human presence intensity. The first parameter deals with habitat destruction or alteration that displaces species, and the second parameter deals with ongoing disturbance to critical species behaviors. Each plant community and animal species is then ranked by a biologist on a four-level scale for degree of severity of impact from each level of land use impact.

There are five ranks that will serve as part of the warnings and recommendations of potential conflict (for plant communities use only 1-4):

Rank 1. Beneficial: The proposed land use will likely be beneficial to the biotic element and/or the land use will cause no harm.
Rank 2. Neutral: The element is expected to be compatible and viable with the proposed land use.
Rank 3. Moderate sensitivity: There are incompatibilities that will likely harm the biotic element, its future population viability, or the human occupants and or their property.
Rank 4. Severe sensitivity: There is a likely total incompatibility between the land use and the biotic element.
Rank 5. The tract has habitat for an animal that is dangerous to people.

II. System Operation

The county planner (or applicant if used as a "front desk" system) would simply click on the parcel of interest, pull down and select a proposed land use and apply any desired filters such as: "assess only state endangered species." The system would automatically report all biotic elements mapped to occur on the tract and indicate the level of conflict between the proposed use and the elements. Mitigation measures for individual elements can then be viewed. The system will also allow query for compatible land uses.

A full description of the system will be available this spring. The authors would appreciate any feedback or suggestions on the use of this system. Send requests and comments to Patrick Crist, GAP, 530 S. Asbury St., Ste 1, Moscow, ID, 83843; pcrist@uidaho.edu, 208-885-3901. Also available is a PDF of the white paper, *Urban Land Use Impacts On Animal Behavior: Science Needs for a Decision Support System* (Crist, 1997) from the same location.

EPIC: From Local Concerns to Global Issues

Will Orr and Brenda Faber

I. Background

The Environmental Planning Information Center (EPIC) is a 3-screen system developed by working closely with local government agencies and city councils. Early design requirements began with Pima County and the City of Tucson in 1991 as an evaluation tool for the Civano Community Development Project.[6] Visualization and decision support capabilities were added with NASA and Urban Consortium (DOE) funding for the Advanced Technology Program at

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6 A sustainable community development project in Tucson for 5000 residents on 1100 acres.

Scottsdale from 1993 to 1997. System development is continuing with the Sustainability and Global Change Program and continued NASA funding at Prescott College in Arizona.

II. System Description

Portable 3-screen theatre:

Right screen: Two-dimensional GIS query and analysis portraying the area of issue in a familiar map format to users.

Center screen: Three-dimensional imagery of this area with a "real-time fly" capability. Any image, draped on a DEM, may be viewed and flown; various GIS layers may be inserted.

Left screen: Decision support software, meeting agenda or PowerPoint graphics.

III. System Uses

Urban planning and the evaluation of alternative land use patterns and development decisions for growing communities is a primary application. The first use of the complete system in Scottsdale for current planning issues received a standing ovation from the City Council in January of 1997. (Note: These are rare...).

The portrayal of global climate change impacts on local areas is a second application and has been utilized at 6 of the OSTP/USGRCP Regional Workshops. Realistically viewing and flying flooded areas at various flood stages or sea level rise has been powerfully effective in conveying the range of potential impacts and suggesting mitigating strategies. The system's flexibility permits its use from simple educational events to interactive public meetings requiring decisions on complex and interrelated issues.

IV. Continuing Development

Additional three-dimensional modeling capabilities are being developed for the middle screen to portray different development and building options. The project team is also working, under NASA funding, to build a model linking local sustainability to global change and coupling this with new decision support software. A range of impact scenarios from local decisions, given the interaction with global change, will be portrayed on the center screen.

Water Resources Information Management System

Paul Weghorst

The Water Resources Information System (WRIMS) is comprised of an ORACLE relational database management system (database) application and an ARC/INFO Geographic Information System (GIS). WRIMS was developed by the Bureau of Reclamation in partnership with cooperating Western State water resources management agencies. This integrated database and GIS is an example of a Decision Support System (DSS) that is in use within the Western United States. WRIMS provides the ability to collect, manage, and analyze water resources information on a regional basis. The software system has been implemented in the Santa Ana River Basin in Southern California, the Central Valley of California, the Salinas River Basin in California, the Snake River basin in Idaho, and the San Luis Valley in Colorado. The system is currently being evaluated for implementation along the border of the United States and Mexico. The database stores water resources related time series data such as stream flow records, diversions records, climatological data, ground water levels, ground water extraction information, and surface and ground water quality. The GIS allows the analysis of the time-series data in graph and map form.

Groundwater and Watershed Modeling Systems as DSS Tools

Cary Talbot

I. Background: GMS

The Department of Defense Groundwater Modeling System (GMS) is a comprehensive graphical user environment for performing groundwater simulations, site characterization, model conceptualization, mesh and grid generation, geostatistical interpretation and post-processing. GMS is developed through the collaborative efforts of 15 different U.S. Government research labs and offices within the DoD, EPA and DoE as well as participation from 20 universities and private industry.

II. Program Features: GMS

Pre- and Post-Processing Support for: MODFLOW, MODPATH, MT3D, FEMWATER/LEWASTE

Site Characterization Tools

GIS/CADD Links

SCAPS & CPT Data Import

Finite Difference/Finite Element Grid Generation

2D & 3D Data Interpolation/Visualization

Geostatistical Library including Kriging (Ordinary, Universal), Inverse Distance Weighting, Natural Neighbor, and Clough-Tocher

AVI Video File Animation

Conceptual Modeling Approach

Connectivity to equivalent surface and watershed modeling systems (SMS & WMS)

III. Background: WMS

The Department of Defense Watershed Modeling System (WMS) is a comprehensive graphical user environment for performing hydrologic analysis. It supports several different models including widely used lumped parameter models as well as more advanced two-dimensional spatial hydrologic models for the purposes of supporting battlefield and environmental missions. Support for the developed system was provided by the Department of the Army and the US Environmental Protection Agency. New features are being added to the system by both agencies to accomplish traditional as well as new missions.

IV. Program Features: WMS

Pre- and Post-processing support for HEC-1 & TR-20 lumped parameter models and CASC2D (fully 2D hydrologic model)

Supports Rational Method and National Flood Frequency Program empirical relationships

Uses NEXRAD radar or Battlescale Forecast Models as input to 2D spatial models

GIS/CADD Links

Finite Difference/Finite Element Grid Generation

2D Data Interpolation/Visualization

AVI Video File Animation

Conceptual Modeling Approach

Connectivity to equivalent surface & groundwater systems (SMS & GMS)

Imports Digital Terrain

A Knowledge Engineering Approach to Natural Resource Management: The Air Quality Information Management System (AQUIMS)

Bruce Nash

Resource management decisions involving air pollution are complex, requiring data and information on local and regional air quality, air pollution effects, and relative sensitivity of resources to different air pollutants. The AQUIMS (Air Quality Information Management System) software provides an efficient, computerized framework for organizing and providing expert interpreted air quality information.

AQUIMS can be used as a stand-alone system, or in conjunction with Microsoft Office and the Internet. After selecting a national park or national wildlife refuge, the user has access to: general site information, a local flora, annotated references on ozone and acid deposition effects, summary air pollutant monitoring information, general information on air pollution effects, slides of pollution-injured plants, spatially-referenced data, and embedded ozone effects and acid deposition decision support systems (DSS). The knowledge bases for each were developed through knowledge engineering sessions with multiple experts using the NetWeaver software developed at Penn State University. The ozone DSS provides the user with diagnostic assistance to identify and quantify ozone injury on native vegetation. Using water chemistry data and encoded knowledge of human experts, the acid deposition DSS characterizes lake/stream sensitivity to natural and anthropogenic acidity. Spatially-referenced data can be interpreted by the knowledge bases to produce spatially-referenced GIS data layers. Providing expert-interpreted information in a quick and more complete manner, makes AQUIMS a useful tool for resource managers and policy experts. The AQUIMS framework can be used to manage information from other natural or cultural resources by adding appropriate databases and developing relevant DSS's.

HAZUS Presentation: A Demonstration of Natural Disasters Loss Estimation Software

Steve Pratt

HAZUS is a natural disaster loss estimation model developed by Risk Management, Inc. for the Federal Emergency Management Agency (FEMA) and National Institute of Building Sciences (NIBS). The program uses a Geographical Information System platform (either MapInfo or ARC Info) to provide loss estimation before or after an event such as an earthquake, flood or hurricane. The program uses mathematical formulas and information about building stock, local geology and the location and size of potential events (i.e. earthquakes) to estimate damages. These estimates include damages to transportation systems, utilities (water, natural gas, electricity, etc.) numbers of people displaced from their homes. Repair costs can also be estimated from this program.

Yellowstone Data Integration and Fly-through Production Using ERDAS, ESRI, and JPL Software

Robert Stevens

Decision Support Systems require the use of complicated spatial scientific data as inputs. This data can be made up of many layers of complex information (i.e., earth imagery, biologic, geologic, socioeconomic, etc.) that is difficult to interpret, and difficult to convey the meaning of, both as an input to the decision making process and as an explanation to support decisions that have been made. Computer-aided visualization of this data can be a good way in which to represent these data, without the problems encountered when trying to use paper map products that have the limitations of dimension, perspective, scale, time, and content. Many visualization products of Yellowstone National Park have been produced by the United States Geological Survey, and these examples demonstrate the usefulness of Visualization in displaying complex information in an easily understandable format. This presentation will display many of these visualization products (both static and fly-throughs), and describe the hardware and software used to create them.

Multiple Attribute Spreadsheet Decision Support System for Conservation Planning

Diana Yakowitz

A decision tool in the form of a spreadsheet program is introduced. The development of this decision support system (DSS) (Yakowitz, Wedwick, and Weltz, 1997) was prompted by the need for objective tools that can be quickly understood and applied to multi-attribute decision making situations. The DSS was designed to implement the solution method proposed in Yakowitz (1996) and Yakowitz and Weltz (1997). A spreadsheet has the advantage of being simple to use and widely understood. The decision support macro is written in a Visual Basic module in the Microsoft Excel8 spreadsheet. Additionally, a user can take advantage of extensive graphing utilities of spreadsheets and customize each application or presentation appropriately. This spreadsheet program is particularly useful for examining environmental alternative management strategies from numerous decision making viewpoints or by multiple decision makers, which could aid in making an informed decision.

Assuming an additive value function, the method quickly computes the possible range of value from the most optimistic to the most pessimistic (best to worst) for any hierarchical arrangement of the attributes or criteria. The user performs the following steps:

Commensurate attribute values or scores are entered into a matrix for each alternative.
A hierarchy of the attributes is built.
A hierarchical structure groups related attributes into decision making categories and subcategories.

The method does not require one to specify or determine explicit weight factors on the attributes or attribute categories. Only a priority order of the attributes at each tier or level in the hierarchy is designated and this priority order can be changed and the value range computed again with the implemented iterative algorithm. The method is well suited to problems involving multiple stakeholders since multiple decision problem structures or priorities can be considered simultaneously. A current project is underway to develop indices of rangeland health using this spreadsheet DSS.

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USGS Energy Resources Program Decision Support System

Marc Levine

I. Issue

Federal, state, and local agencies have an increasing need for geological science data and information to support their responsibilities in land management, environmental policy and regulation, Native American trust issues, National energy policy, and economic analysis. Moreover, energy related data and information are commonly required for rapid response to emerging issues.

II. Solution

The USGS Energy Resources Program is developing an interactive Decision Support System (DSS), that will make available, via the Internet, map coverages and datasets required for decision making on energy related issues. This system will integrate various databases of USGS scientific investigations with state-of-the-art digital and Internet capabilities to provide a scientific Decision Support System comprising comprehensive National geospatial coverage and Internet accessibility for rapid analysis of emerging issues. The DSS will include capabilities for user-driven GIS (geographic information system) mapping and user-defined queries of coverages and active, production databases which will be linked from several sources.

Web-based Land Use Planning and Management

Jon Bartholic and Da Ouyang

Land use planning and management requires combining a great deal of information such as soils, land use/land cover, agricultural systems, and watershed characteristics. The Institute of Water Research at Michigan State University has developed a Web-based integrated information system as a decision support tool for land use and natural resource management. This system provides information to assist landowners and natural resources managers who are seeking assistance with conservation planning. It also assists partners and field staff with conservation planning activities. The Web-based system consists of several components including GIS integrated land use/land cover, soils; tools for nutrient/pesticide application, water quality/quantity management, and technical resources. In the soils component, digitized soil mapping and soil property information are available. The pesticide component was developed based on National Agricultural Pesticide Risk Analysis (NAPRA). The NAPRA process considers climate, soils, pesticide properties (i.e. toxicity and persistence), tillage practices and field slope as well as slope length. Given regional climate, the process can be used to identify soils and tillage, which are susceptible to pesticide losses. By comparing different practices and management alternative scenarios, approaches for minimizing environmental risk can be identified. The water quality component includes information from the U.S. EPA's STORET database and TMDL (Total Maximum Daily Loads). Users can search water quality information on a county or watershed basis. The Internet map server is also used in the system to present pesticide risk areas and polluted reaches.

Agricultural Water Resources Decision Support System (AWARDS)

Al Brower

AWARDS is an automated information system to assist water users by providing easy access to rainfall and daily crop water use estimates. The system uses modern remote sensing, communication, computer, and Internet technologies, including NEXRAD radars and ground based weather stations, to estimate rainfall and evapotranspiration. Precipitation estimates can provide an early warning component for watershed management and public safety. The Bureau of Reclamation has demonstrated the effectiveness of the system in Southwestern Oklahoma, and is expanding the technology to the Rio Grande River basin in New Mexico and to the Rogue River basin in Southwestern Oregon. Reservoir operators, water managers, and on-farm water users access the AWARDS system products via the Internet to make their operational decisions.

A Database-Centered Decision Support System for the Watershed and River System Management Program (WARSMP)

G.H. Leavesley, T.J. Fulp, S.L. Markstrom, M.S. Brewer, R.J. Viger, R.S. Parker, G. Kuhn, and D.L. King

The interdisciplinary nature and increasing complexity of environmental and water-resource problems require the use of modeling approaches that can incorporate knowledge from a broad range of scientific disciplines. The integration of such modeling capabilities and their application to water-resources management is a major focus of the Watershed and River System Management Program (WARSMP).

WARSMP is a cooperative effort between the U.S. Geological Survey (USGS) and Bureau of Reclamation (BOR) to develop an operational, database-centered, decision support system (DSS) for application to complex, water-management issues. The DSS couples the USGS's Modular Modeling System (MMS) with the BOR's RiverWare tools using a shared relational database. MMS facilitates the integration of a wide variety of models and their application to water- and ecosystem-resource management. RiverWare is an object-oriented reservoir and river-system modeling framework developed to provide tools for evaluating and applying optimal water-allocation and management strategies to complex, operational decisions on multipurpose reservoir systems and watersheds.

The purpose of this demonstration is to provide an overview of the concepts and capabilities of the database-centered DSS, using an application to the San Juan River basin. The DSS provides reservoir operators and water-resource planners the ability to evaluate alternative strategies or scenarios to meet multiple basin-management objectives under uncertain hydrologic conditions. These objectives include meeting water demands for irrigation, municipal, and industrial uses, power generation, flood-safety requirements, and critical habitat for endangered species.

As one example of the scenario process, a critical habitat for endangered fish downstream from Farmington, NM, is examined. An issue in constructing or maintaining a stream habitat is providing sufficient streamflows to remove fine-grained bed material from the cobble bed. The ability to provide such flows needs to be examined with regard to the other concurrent water demands on the system. About half of the upstream flow for the study reach comes from the Animas River, which is unregulated, and the remaining flow comes from the San Juan River, which is regulated by Navajo Reservoir. Because of the flow combination, it is necessary to predict both inflow to the reservoir and streamflow in the Animas River. The combined flows of the Animas River and the releases from Navajo Reservoir are needed to provide sufficient flows to remove the fine-grained bed material at the appropriate point in the spawning season. Alternative scenarios to provide the needed flows, given concurrent water-demand constraints, are evaluated.

MLRA Revision Through Aggregation of STATSGO

Vern Thomas

The Natural Resources Conservation Service (NRCS, formerly SCS), in conjunction with the Consortium for International Earth Science Information Network (CIESIN), developed to revise Major Land Resource Areas (MLRA) delineation using State Soil Geographic Data Base (STATSGO) polygon data. This process supports a three year interagency ecological mapping effort led to a Memorandum of Understanding in which these agencies agreed to develop a Spatial Framework of Ecological Units (often referred to as Aeco-regions) of the United States. Agency participants include NRCS, USFS, BLM, USGS, NPS, F&WS, NBS, ARS, and USEPA. NRCS has a 60-year history using MLRAs to deliver national conservation programs to the private land owner. In 1996, NRCS began to revise the 1984 version of MLRAs (1:7,500,00 scale) through the aggregation of STATSGO polygon delineations (1:250,000 scale). The main benefit of this effort is the logical linkage between two formerly separate and independently created data sets, MLRA vs. STATSGO. Using the expert knowledge of NRCS soil scientists with the larger scale of the STATSGO data, a new more precise and accurate national MLRA approximation is generated. Using STATSGO data, soil scientists may examine the landscape in terms of soil complexes, surficial and bedrock geology, land use/land cover, climate data, topography, and other reference data in a GIS.

Working with NRCS personnel, the Active Response Geographic Information System (AR/GIS) team of CIESIN has created a powerful spatial decision support system for the soil scientist using ArcView GIS and AR/GIS customized functionality. This functionality facilitates iterative reclassification of MLRA concepts according to STATSGO polygons and identifies data errors and misclassifications. Each reclassification set can be traced through the use of rationale files created by the soil scientist and are attached to each reclassified polygon record. The system expedites refinement of MLRA delineation using STATSGO polygons to generate a new MLRA map data set that contains new, more precise and accurate delineations that capture soil scientist expertise, knowledge, and spatial reasoning. The system also eliminates the need for re-digitizing new MLRA lines.

Environmental Impact and Mitigation Assessment for Mining Related Development

Vern Thomas

The process for obtaining a permit for a single mine exploration or development proposal requires multiple agency and discipline reviews, and a great deal of time (3 - 5 years) and incurs a high monetary cost for both the mine development company and land management agencies. Each mining proposal is required to go through a separate Environmental Impact Statement (EIS) that is required by the National Environmental Policy Act (NEPA) permitting process. NEPA permitting process requires all Federal agencies to consider the values of environmental preservation for all significant actions and prescribe procedural measures to ensure that those values are fully respected. Federal agencies are required to systematically assess the environmental impacts of proposed actions and consider alternatives that are less damaging to the environment. All agencies must use a systematic interdisciplinary approach to environmental planning and evaluation of projects that may have a negative affect on the environment.

CIESIN and Cedar Creek Associates (Fort Collins, CO) demonstrated a streamlined and efficient assessment approach in which an entire programmatic area (claim block) is submitted for NEPA approval. Here, any proposed exploration or small mine development within the programmatic area would be submitted as a Notice of Intent (NOI) to the appropriate Federal land agency for approval. Included in the NOI would be the potential environmental impact and mitigation required for appropriate reclamation of impacted areas. This programmatic area approach is ideally suited for analysis using Arc/Info GIS modeling and custom ArcView GIS applications for decision making. GIS integrates spatial and non-spatial environmental and engineering data to create predictive surfaces (e.g., vegetation) across the entire programmatic study area. Using the predictive surfaces and other relevant spatial data along with custom ArcView GIS applications, the user can create mining scenarios and quickly evaluate each scenario in terms of environmental impacts, required legal (permitting) mitigation decisions to be made by the Federal land agencies, as well as economic cost/benefit consequences. The customized ArcView scenario builder and evaluation system can be made available to agency oversight personnel allowing them to examine all input parameters and mitigation logic. If the oversight personnel agree with the predictive surfaces and impact mitigation logic, the programmatic area would be approved as a whole. The mining company could then create exploration and mine scenarios to submit to the appropriate Federal land agency district personnel as a NOI. Each NOI would include the proposed development, as well as all potential environmental impacts and mitigation activities. The custom ArcView project may also be sent to district personnel.

INFORMS: A Framework for Project Planning

Steve Williams

INFORMS is a decision support framework designed specifically for the Forest Service IBM platform; it is used to assist forest/district-level users in resource project management to make decisions following the NEPA process. INFORMS was engineered to support planning tasks associated with watershed and project-level planning but has application for other planning and decision support activities.

The INFORMS application utilizes a customized ArcView interface with numerous supporting Oracle forms. The underlying Oracle data structure behind INFORMS supports numerous planning functions, including the ability to:

Support the entire NEPA process and improve decision quantity and quality;

Capture and isolate project or decision support data sets from corporate spatial and attribute databases;

Define project team members and define their access to INFORMS functions;

Access and run a range of analytical tools such as models (E.g., FVS), scripted queries, Arc Macro Language routines, and rulebases (a knowledge-base component);

Build and retain project alternatives via ArcView themes and Oracle datasets; and

Track progress on projects and decisions via access to an event log or record of decisions.

Analytical tools used via INFORMS will vary from site to site since users at each site determine the suite of tools they wish to integrate within INFORMS. INFORMS is currently installed on 13 sites, encompassing all but one Forest Service Region.

Existing user/test sites include the following:

Jessieville Ranger District, Ouachita NF

Hayden-Brush Creek Ranger District, Medicine Bow/Routt NF

Angelina Ranger District, National Forests in Texas

Chippewa NF

Huron Manistee NF

Kistachie NF

Tongass-Sitkine Area Office, Alaska

R-1 Regional Office

R-6 Regional Office

R-5 GIS-Remote Sensing Lab, Sacramento

GIS COE, Ogden, Utah

Wallowa-Whitman NF

Beaverhead/Deerlodge NF

The Boulder Geoenvironmental Explorer: A GIS Tool to Communicate Science to Land Managers and the Public

Anne McCafferty, D.B. Yager, and T.C. Sole

The Boulder Geoenvironmental Explorer (BGE) is a prototype, PC-based viewing tool that permits visualization of the spatial relationships between diverse abandoned-mine lands earth-science data sets for the Boulder River watershed. The prototype also includes data and interpretive products from the state geoenvironmental assessment of Montana. Information from the state-wide assessment was used in the planning process to select the Boulder River watershed for detailed study. The BGE is being utilized for a collaborative and interdisciplinary approach to problem solving, which is central to watershed studies. This tool provides a coherent, readily accessible database and greatly enhances our ability to recognize relationships between diverse data layers. Data layers provided in the BGE includes geologic, mine, cartographic, hydrologic, and biologic data as well as related interpretive geologic, geochemical, geophysical, and wetlands models from the U.S. Geological Survey (USGS) and U.S. Forest Service.

Features found in BGE include a customized graphical-user interface developed by the USGS in cooperation with Environmental Systems Research Institute, Inc., unified and updatable data formats, object oriented programming, geographic information system (GIS) capabilities, and accessibility from either a CD-ROM or Web site. BGE was designed to be used by non-technical users in a shared work environment. The software will be installed on a USGS Web site and used by team scientists as a data management tool for updating data and interpretations and communicating new information between team members and cooperators. Following completion of the watershed study, a CD-ROM and a Web-site application will be made available to the public for land-use planning purposes, educational use, or further scientific studies.

The Spatial Data & Visualization Center's Internet Map Server: A Prototype Information Delivery System for the Greater Yellowstone Area

Henry Heasler, Jeffrey Hamerlinck, and Steven Gloss

The Spatial Data and Visualization Center is a multi-disciplinary research and technical service center at the University of Wyoming. The focus of the Center is the advancement and application of geographic information science and related spatial technologies. The SDVC is currently developing a unique suite of graphical, Internet-based display, query, and retrieval tools for access to and utilization of available spatial digital data for major resource regions in the State of Wyoming, including the Greater Yellowstone Area.

Under development for the last 18 months, the SDVC's Wyoming Geologic Database (WGDB) has served as the prototype for the SDVC's Internet Map Server (IMS) query and display engine. The WGDB IMS has been designed to allow non-GIS professionals Internet access to the vast amount of spatial digital data currently available through the SDVC. The application is built upon the Environmental Systems Research Institute, Inc. (ESRI; Redlands, CA USA) Internet Map Server and other ESRI technologies. The IMS has basic ArcView display capabilities, which are enhanced with SDVC proprietary query capabilities customized into a logical and simple Internet user's interface. This interface provides tools (accessible via the Internet) that can be used to gather, display, analyze, and interpret geospatial information. Thus, the SDVC's Wyoming Geologic Database IMS facilitates the utilization of geospatial information by the general public, businesses, schools, resource managers, and other non-GIS professionals.

In parallel to the WGDB IMS, the SDVC has been developing its spatial data warehousing capabilities through the Wyoming Natural Resources Data Clearinghouse, Wyoming BioInformation Node, and the Snake River Corridor Geospatial Data Node. These efforts, all compliant with Federal Geographic Data Committee and National Spatial Data Infrastructure standards for data serving and metadata documentation, respectively provide statewide, theme-specific and geographically-based means for accessing and downloading both spatial and non-spatial digital data maintained by the SDVC.

A near-term goal of the SDVC is to link the graphical user interface of the IMS with the data acquisition capabilities of the various clearinghouse entities supported by SDVC. Great potential exists for developing customized, queries and data retrievals by combining these technologies with an object-based data engine. Opportunities for providing decision support in a wide range of Greater Yellowstone Area management activities is strongly being considered as an initial testbed for these applications through the SDVC concept of a Greater Yellowstone Science Information System.

The Contaminant Assessment Process (CAP): A Data Analysis System for Evaluating Environmental Contaminant Threats to DOI Lands and Species

Jim Coyle

The Contaminant Assessment Process (CAP) was developed by the US Geological Survey (USGS) Biological Resource Division's Biomonitoring of Environmental Status and Trends (BEST) program. The CAP is a standardized approach for assessing threats posed by environmental contaminants to refuges, national parks and other lands managed by the Department of the Interior (DOI). The CAP is divided into two parts: a retrospective analysis and, if needed, field sampling. The retrospective analysis is a synthesis of existing information. Steps include description and review of the ecological characteristics, management goals, and habitats of importance for the land unit, delineation of transport pathways; identification of sources, including point and non-point, and associated contaminants; identification of potentially sensitive species; and evaluation of contaminant issues and ranking of their relative risk. If needed, field sampling is conducted to further evaluate a potential problem or to establish baseline conditions.

Information assembled in the retrospective analysis is used to define sampling objectives, to select appropriate methods, and to define sampling designs. Results from the field sampling are interpreted and the findings are reported to land managers.

Through the CAP, users identify and document contaminant sources and transport pathways for a DOI land unit. The approach identifies and evaluates contaminant sources and types, evaluates potential of potential threats, and supports the development of focused contaminant investigations. The CAP provides decision-support information for land managers and contributes to developing management options to minimize impacts. The process is designed to help managers answer the following types of questions:

Are environmental contaminants likely to reach a land unit?
Are environmental contaminants reaching a unit likely to harm species or habitats?
Are further investigations warranted to evaluate risks?
Are management actions available to minimize impacts?

Data management for the CAP is achieved using an Internet-accessible system developed though joint funding by the U.S. Fish and Wildlife Service and the BEST program. The system was developed by programmers of the USGS's Midcontinent Ecological Science Center in Ft. Collins, Colorado. Hardware, stored tabular and spatial data along with program code (including AC@, AHTML@, AJAVA@ and ORACLE@) constitutes the data management system residing on the MESC server.

Overview of VegSpec: A Decision Support Tool for Vegetation Selection

Wendell Oaks

VegSpec, a USDA-Natural Resources Conservation Service decision support tool, provides a potential list of adapted plants based on site characteristics and user objectives. Using soils, climate, and Major Land Resource Areas assists the user in describing the site to be revegetated. In the second step, the user identifies their purposes and objectives including any limitations on the types of plants (i.e., native verses introduced). Users can specify only trees or grasses or *forbs* or include all 2570 species and *cultivar* combinations. In the first version (September 1997) VegSpec provided only a potential list of plants and the attributes of these plants. In version 2.0, VegSpec provides the capability to fully identify potential plants and construct a planting design. Seeding and planting calculations are done using expert systems embedded in the application. VegSpec provides a report describing the site, the user requirements, potential plants, selected plants, seeding and planting spreadsheets, and establishment recommendations. VegSpec was developed in partnership with USGS-Biological Resources Division, US ARMY, and NRCS over the last 3 years.

Watershed Analysis Risk Management Framework (WARMF): A Decision Support System for Watersheds

Robert A. Goldstein and Carl Chen

WARMF provides a road map to guide stakeholders to a consensus watershed management plan. All necessary databases, simulation models, and graphic software are integrated into a Windows GUI. The road map contains seven steps. Step 1 is for stakeholders to learn about themselves and to get organized. Step 2 is for stakeholders to develop a consensus work plan. Step 3 is to identify water quality issues. Step 4 is to learn how the watershed system works. Step 5 is to devise and evaluate management alternatives. Step 6 is to analyze cost/benefit and cost sharing schemes. Step 7 is to debate and reach consensus using a nominal group process.

A context-sensitive help menu is provided every step of the way. An uncertainty analysis can be performed to evaluate the chance of failing to achieve the water quality objective for a plan that may involve multi-million dollars of private and public investments. Thus, by pointing and clicking the tasks in each step, WARMF presents stakeholders with relevant information in a logical manner so that they can understand and make informed decisions. The models, embedded in WARMF, can educate stakeholders on how meteorology generates hydrology and *nonpoint* loads; how land use changes affect nonpoint loads; how point and nonpoint loads are spatially distributed; how point and nonpoint loads translates to water quality in rivers and lakes; and whether the water quality can support the intended uses. The reliability of the models can be checked by comparing the simulated results to the observed data. WARMF has been applied to Catawba River Basin of North and South Carolina, Holston River Basin of Tennessee and Virginia (TVA), and Hockanum River Basin of Connecticut. The capability to determine TMDLs with a bottom-up approach is being added.

Knowledge-Based Decision Support for Landscape-Level Ecological Analysis

Keith Reynolds

The USDA Forest Service Pacific Northwest Research Station in Corvallis, Oregon, has developed the Ecosystem Management Decision Support (EMDS) system. The system developed by Dr. Reynolds and colleagues integrates the logical formalism of knowledge-based reasoning into a GIS environment to provide decision support for ecological landscape assessment and evaluation. The knowledge-based reasoning schema of EMDS uses an advanced object- and fuzzy logic-based propositional network architecture for knowledge representation. The basic approach affords several advantages over more traditional forms of knowledge representations, such as simulation models and rule-based expert systems. The system facilitates evaluation of complex, abstract topics such as forest type suitability that depend on numerous, diverse subordinate conditions because EMDS is fundamentally logic based. The object-based architecture of EMDS knowledge bases allows incremental, evolutionary development of complex knowledge representations. Modern ecological and natural resource sciences have developed numerous mathematical models to characterize very specific relations among ecosystem states and processes. However, it is far more typical that knowledge of ecosystems is more qualitative in nature. Approximate reasoning, as implemented in fuzzy logic, significantly extends the capability to reason with the types of imprecise information typically found in natural resource science. Finally, the propositional network architecture of EMDS knowledge bases allows both the ability to evaluate the influence of missing information and the ability to reason with incomplete information.

The first production version of the system was released in February 1997. The USDA Forest Service, in cooperation with other federal and State partners, is currently applying the EMDS system in three ecoregional assessments now underway in the US. Since its initial release, EMDS has been requested by 70 natural resource institutions worldwide, including 18 universities, 32 national research and/or management organizations, 10 state/province level organizations, and 5 international research institutes.

SMART PLACES: A Tool for Exploring Land Use Alternatives

Brenda Faber and Bill Langer

Smart Places is a land use decision support tool. It enables land managers to interactively develop and evaluate alternative land use scenarios. The impacts of alternative scenarios are assessed within the context of project objectives and constraints.

Smart Places assists resource managers in producing a range of carefully considered options, an evaluation of the impacts of each option, an audit trail tracking the decision rationale for each approach, and a geographic blueprint for implementation.

Smart Places is an ArcView extension. It expands the power of ArcView to provide a customizable framework for land use decision support. Extended capabilities include:

selectable user levels;
automatic calculation of attributes for new and existing geographic features;
automatic constraint compliance checking for new and existing geographic features;
user modification of attribute calculation formulae and constraint target values;
storage and retrieval of entire design scenarios;
comparison of multiple land use scenarios;
configurable links to empirical resource analysis models;
automatic results visualization and report generation;
spatial group negotiation tools for collaborative planning.

Smart Places was developed in collaboration with the City and County of Denver, the Colorado Governor's Office of Energy Conservation, Electric Power Research Institute, Public Service Company of Colorado, Urban Consortium Energy Task Force, and the Consortium for International Earth Science Information Network (CIESIN). The system was initially used for redevelopment planning on the former Stapleton Airport site in Denver, Colorado. Since that time, Smart Places has been successfully applied in a number of projects involving urban planning, resource management, sustainable development, and direct public involvement. Smart Places can operate in a stand-alone mode or in a local area network configuration for collaborative planning workshops.

Hierarchical Decision Support Tools for Land Management Planning

Dan Camenson

Land management planning covers a very broad range of problems. Temporally, operating plans stipulate what is to happen over the course of the next few weeks while long range strategic plans are developed for planning horizons in excess of 100 years. Spatially, decisions address areas ranging from several hectares to hundreds of thousand of hectares. Managerially, decisions are made at all levels of the organization. In the past, we have tried to build comprehensive monolithic systems to satisfy all the needs with little success. A hierarchical approach to planning with direct links between the various levels of the planning process seems appropriate.

The U.S. Forest Service uses three primary software systems to foster a hierarchical framework to land management planning. Spectrum is the system used to carry out strategic analysis where the primary function is to analyze issues across large landscapes and establish appropriate output levels. RELM is used to conduct tactical analysis of the strategic solution by desegregating it to smaller subunits where standards and guidelines at that scale can be tested. SNAP is used for operational analysis where individual projects are planned in an attempt to meet the outputs passed down from the tactical model. At the operational level, spatial considerations are explicitly tested. Failure at any level in the hierarchical provides feedback to the previous level, which must be modified to ensure implementation of the solution.

APPENDIX A

CHARTER

The Interagency Coordination Group on Decision Support for Land and Natural Resource Management

Purpose and Background

The purpose of this charter is to establish an interagency group to coordinate, communicate, and advance the concepts of decision support for Federal, State, and local managers of public lands, natural resources, and other elements of ecosystems.

For such managers, the challenge of managing lands and making decisions in support of mission objectives has become increasingly complex. The competition for the land resource is growing more intense (particularly those in proximity to growing urban and recreation areas), a larger number and variety of stakeholders are demanding participation in local and regional decisions, the amount of data and information associated with issues is growing exponentially, and our understanding of ecosystems and our impacts on them is growing as well, albeit more slowly.

Many individual tools — to analyze data, display geographic information, or model impacts of proposed activities — have been and are being developed. But the integration of such tools into practical support for the managers and decision makers has not evolved as quickly.

Vision

The Interagency Group on Decision Support for Land, Environmental, and Natural Resource Management (IGDS) will work at the juncture of management and stakeholder needs, evolving computer and modeling capabilities, and scientific understanding of ecosystems to ensure that the best and most effective decision support tools and capabilities are available to managers of public lands and natural resources.

Mission and Goals

The mission of the IGDS is to encourage the use and advance the state-of-the-art of land, environmental, and resource management decision support tools and systems. The goals are:

to better achieve effective decision support capabilities for ecosystem management through collaboration, and establish a process for working towards a next-generation decision

support capability;
to develop, distribute, and regularly update understanding of existing decision support capabilities;
to identify manager and stakeholder needs not currently met;
to facilitate the integration of evolving scientific understanding into decision support;
to identify emerging technologies and describe how they may contribute to decision support; and
to provide a forum for the interaction of users, designers, and contributors to the long term development of decision support.

Membership is open to any Federal, State or local government agency with an interest in decision support for land and natural resources, and to others with such interest, consistent with the rules and intent of the Federal Advisory Committee Act.

Strategic Goal

To develop decision support systems, tools, and services that are practical, open, accessible, and at, or moving towards, state-of-the-art. *Practical* implies that they assist managers in making better, faster, or more efficient decisions; *open* means that they can incorporate features and capabilities from multiple sources, and that creative and innovative improvements can be quickly and easily integrated; *accessible* means that managers and others (with appropriate controls) are able to quickly and easily take advantage of its capabilities; and *state-of-the-art* means that there are technical and organizational mechanisms in place to rapidly identify, transfer, and replace or incorporate new understanding or features. A beginning list of features and components that would contribute to this goal include:

A system design that 1) is accessible and useful to a range of stakeholders; 2) does not require unusual or expensive hardware or software; 3) uses and facilitates the use of distributed data bases, modeling and simulation capabilities; 4) provides mechanisms to display and explain the sources and implications of uncertainty; and 5) stresses and encourages modularity and interoperability in order to maximize the return on investments in tools.

Decision support tools and services such as 1) physical, biological, cultural, and economic data bases, both spatial and non-spatial; 2) geographic information systems to display and manipulate spatial data; 3) descriptive and predictive models to evaluate trends and impacts of actions; 4) simulation capabilities to assist in evaluating complex, interacting systems, issues and strategies; and 5) visualization and similar tools to most effectively display and communicate results to multiple audiences.

Involvement mechanisms to 1) allow participation of not only manager, but by scientists, engineers, citizen groups and individual stakeholders; 2) assist participants in identifying and characterizing issues, and exploring and implementing decisions; and 3) recognize and explicitly address multiple and possibly competing goals and objectives.

The State of the Art

A Decision Support System (DSS) can be generally defined as an interactive, computer-based tool or collection of tools that uses information and models to improve both the process and outcomes of decision making. This definition provides three ways of assessing the "state of the art" of decision support: whether it helps to improve elements of the decision process, whether the range of tools available and the systems for combining them are adequate, and whether outcomes of decision processes are improved. As part of this workshop, a feedback form (attached) was developed which provides an opportunity to express opinions on two of these three dimensions: the decision process, and characteristics and tools. The third, outcomes, may be the subject of future workshops.

I. The Decision Process Framework

One way to consider the value of decision support is from the perspective of the decision making process. One description of the decision process, presented at the workshop, is summarized below. In this description, there are six stages, with appropriate information and other feedback loops as necessary. The process is initiated by or in response to a condition, event, or situation that directly or indirectly affects land, water or living resources, and that convinces at least some stakeholders that there is a problem to be solved or an opportunity to be realized.

The stages are:

Mapping the decision — deciding how the decision will be made and who will make it;

Framing the Problem — describing the problem to be solved, and defining success;

Gathering Intelligence — data, information, expert judgement and stakeholder input;

Evaluating/Selecting Alternatives — using one or more criteria and objectives;

Implementing the decision; and

Learning from the process, and modifying or adjusting the process or decisions.

This description of the decision process is not unique, nor is it suggested that, if followed, good decisions will necessarily result. Rather, it is intended to identify the steps intrinsic to any decision process, whether or not the time and effort spent on each is appropriate, and whether or not the outcome is successful. The purpose of the framework for this workshop is to provide a more desegregated basis for questions about the adequacy of existing decision support systems or tools. In the workshop feedback form attached, you'll be asked to provide your assessment about support for decisions at each of these stages.

II. Decision Support Characteristics and Tools

Another way to view the adequacy of decision support is in terms of available tools and characteristics. Frequently the analogy of a toolbox is used — a collection of capabilities, not all of which are needed for any specific task, and not all of which would be used by any individual, but all of which are available, appropriate for some task, and capable of being used together. In addition, there are characteristics of the toolbox itself that can affect its overall utility; for example: flexibility, cost, and, durability.

Some of the demonstrations in the workshop are systems with their own characteristics and set of tools; others are single purpose tools; and others are ideas for new tools or toolbox capabilities. Are the tools and toolboxes sufficient for managers and other stakeholders? Are some aspects well covered while others are not? Assessing the state of the art in decision support for managers and others concerned with land, natural resources, and the environment means assessing both the systems or toolboxes, and the tools to be used with them.

A candidate list of characteristics — things that enhance the overall functionality of a system, and a list of tools, both developed by the interagency group — is provided separately below.

Characteristics include:

- Readily accessible and affordable hardware and software;
- Intuitive and adaptable user interfaces (including adaptability to different levels of user sophistication);
- Modularity to allow incremental development and "Lego" like construction of systems;
- Internet connectivity and ability to use distributed databases and models;
- Interoperability to allow use of components regardless of where they are developed; and
- Logging and tracking to document decision processes and facilitate records of decision.

Tools include:

- Geographic Information Systems capabilities;
- Ability to accept and utilize real-time data;
- Ability to access and utilize textual material;
- Ability to select different geographic and temporal scales;
- Modeling and simulation tools;
- Visualization tools to display data, relationships, and anticipated results;
- Mechanisms to allow structured stakeholder involvement;
- Tools to facilitate adaptive management and monitoring;
- Means to depict uncertainty in data, relationships or results;
- Explicit methods to treat multiple goals, objectives, and measures; and
- Ability to create and store scenarios.

APPENDIX B

ATTENDANCE

Name	Organization
Bob Alexander	USGS
Carl Almquist	BLM-OR
Roger Barlow	USGS/NMD
Jon Bartholic	MSU
Susan Benjamin	USGS/EDC/NMD
Laura Biewick	USGS
Dale Boland	USGS/NMD-WMC
Mike Brewer	USGS-Denver
Bill Broderick	Denver Region Council of Gov'ts
Al Brower	USBR
Andy Bruzewicz	USACE-RSG-ISC
Dan Camenson	US Forest Service
Joe Campbell	USDA-FS
Carl Chen	EPRI/Systech
Dave Cleaves	USDA Forest Svc
Joe Cornellisson	MMS
Thayne A. Coulter	Bureau of Rec. Tech. Service Cntr.
Jim Coyle	USGS/BRD
Patrick Crist	USGS/BRD
Mike Crome	EROS Data Center
Frank D'Erchia	USGS/BRD
Diana Dugas	USGS/WRD
Brenda Faber	Fore Site

Mark Feller	USGS/NMD
Dave Ferderer	USGS-CR Energy Team
Harvey Fleet	USGS/BRD
Tom Fouch	USGS/GD
Ann Frazier	USGS
Don Frevert	USBR
Terry Fulp	USBR/LC
Len Gaydos	USGS
Sarah Gerould	USGS-Reston
Steven P. Gloss	Univ. of Wyoming
Dave Greene	USGS/NMD
Thomas Gunther	AS/WS-DOI
Jeff Hamerlinck	Univ. of Wyoming
Dave Hamilton	USGS/BRD/MESC
Bill Hansen	Corps of Engineers
Tom Hart	U.S. Army Corps of Engineers
Henry Heasler	Univ. of Wyoming
Karl A. Hermann	EPA
Eric Hesketh	USDA-NEC
Shari Jackson	Concord Consortium
Jim Jancaitis	USGS/NMD
Ralph Johnson	MMS
Hoyt Johnson III	Prescott College
John Kelmelis	USGS
Dave King	USBR
Tom Kohley	UW-SDVC
Karen Koltes	USGS/BRD
Gary Krizanich	USGS
Gerhard Kuhn	USGS-Denver

Beth Lachman	Rand/CTF
Deena Larsen	USBR
George Leavesley	USGS
Marc Levine	USGS/GD
Barney Lewis	USGS/GD
Pat Mangan	Reclamation
Steve Markstrom	USGS/WRD
Dave Matthews	USBR
Anne McCafferty	USGS-Denver
Ron Meekhof	USDA
Bruce Miller	PA State Univ.
Carol Mladinich	USGS
Serrina Monnin	BLM
Todd Mowrer	USDA, Forest Svc.
L. David Nealey	USGS/GD
Earl Nelson	WAPA
Bill Newland	BLM
B.L. Niemann	EPA
Ray Obuch	USGS
Will Orr	Prescott College
Mike Pantea	USGS/Energy
Randy Parker	USGS
Francine Patterson	UMV of Denver
Geoff Plumlee	USGS/GD
Stephen Ragone	S.E. Ragone & Assoc.
Don Ralston	USBR
Keith Reynolds	USDA/FS
Randy Schumann	USGS
Deborah Shields	USDA/FS

Phil Smith	NRCS
Rick Sojda	USGS
Tracy Sole	USGS-Denver
Joe Spinazola	Reclamation
Bob Stevens	USGS/NMD-MAC
Mike Stier	USGS
Peter Stine	USGS/BRD
Ron Sundell	Argonne Nat'l Lab
Dave Swanson	WAPA
Cary Talbot	USACE-WES
Vern Thomas	CIESIN
Mark Treviño	USBR
Jim Turner	BLM-NARSC
Roland Viger	USGS/WRD
Craig Wandrey	USGS/Energy
Ray Watts	USGS/NMD-RMMC
Robert Weissler	RAND
Jim Westervelt	Corps of Engineers
Steve Williams	USDA/FS
Diana Yakowitz	NSDA/ARS
Paul Young	USGS
Rich Zirbes	USGS

*U.S. Government Printing Office: 1999 — 453-036