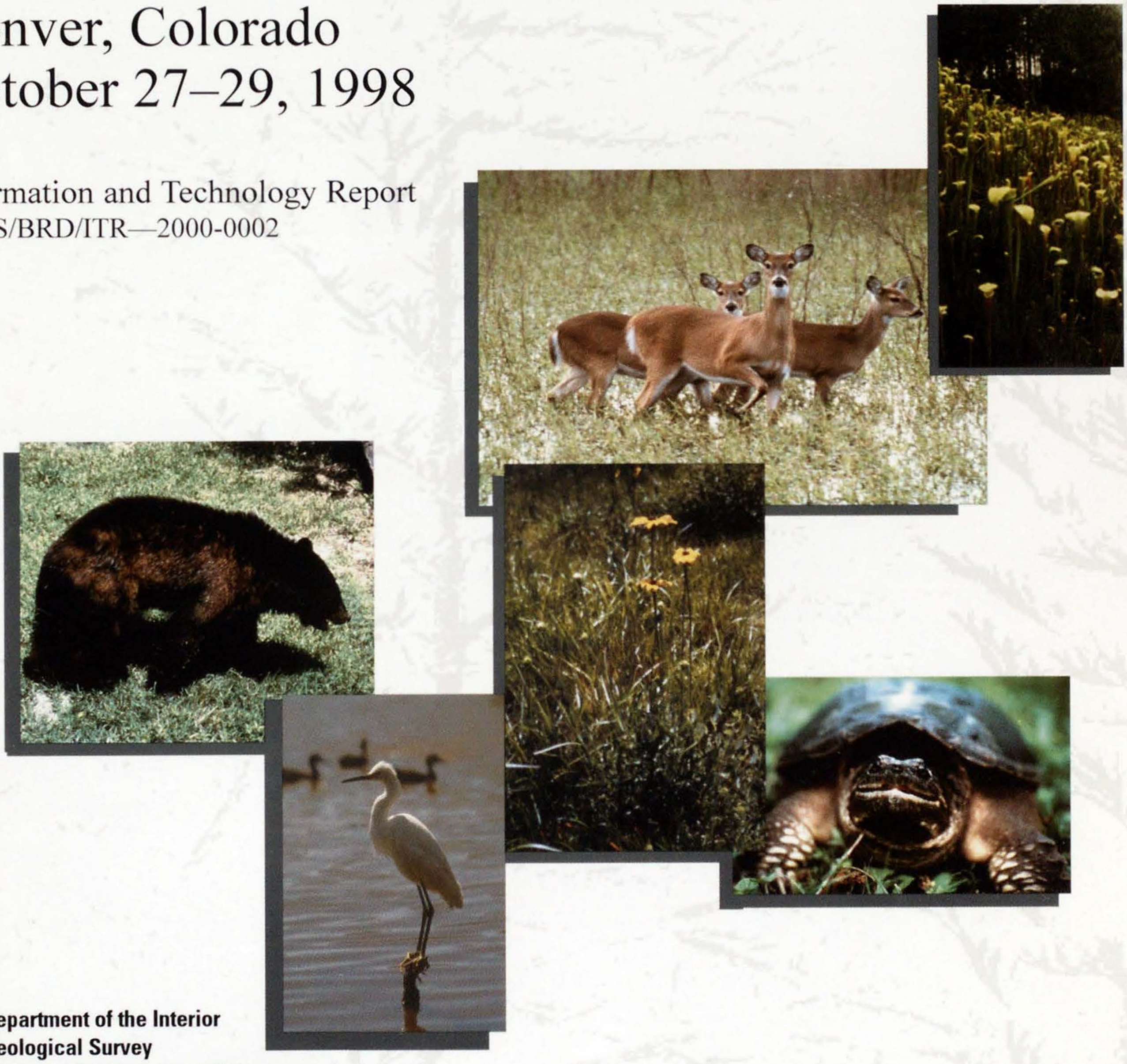
Proceedings of the Workshop "Development of Biological Decision Support Systems for Resource Managers"

Denver, Colorado
October 27–29, 1998

Information and Technology Report
USGS/BRD/ITR—2000-0002



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December 1999

Compiled and edited by
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Center for Biological Informatics
Denver, Colorado 80225-0046

Suggested citation:

Getter, J., T. D'Erchia, and R. Root (editors). 1999. Proceedings of the workshop "Development of Biological Decision Support Systems for Resource Managers," Denver, CO, October 27–29, 1998. U.S. Geological Survey, Biological Resources Division, Information and Technology Report USGS/BRD/ITR–2000-0002, Denver, Colorado. v + 41 pp.

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Proceedings of the Workshop "Development of Biological Decision Support Systems for Resource Managers"

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Compiled and edited by
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This workshop was sponsored by the U.S. Geological Survey (USGS) Office of Biological Informatics and Outreach and was hosted by its USGS Center for Biological Informatics in Denver, Colorado. Additional financial support was provided by the National Biological Information Infrastructure program.

Abstract: The format for this 3-day workshop (27–29 October 1998) included plenary presentations by USGS Biological Resources Division (BRD) and U.S. Fish and Wildlife Service personnel who use and develop decision support systems (DSS); breakout sessions addressing DSS technical information aspects, outreach/ customer requirements, and future perspectives; and a DSS Steering Committee meeting to evaluate workshop goals and to provide guidance for future efforts. Steering committee action items developed from workshop inputs were to (1) develop a "DSS framework" document for use in biological research, (2) develop a "proof of concept" DSS based upon the framework document, and (3) integrate decision support systems into BRD program elements.

Key words: Biological Resources Division, decision support systems, DSS, GIS, USGS

Introduction

In late summer 1998, the U.S. Geological Survey (USGS) Chief Biologist, Dennis Fenn, requested that the Associate Chief Biologist for Information, Gladys Cotter, host a Biological Resources Division (BRD) workshop on decision support systems (DSS). In response, the Office of Biological Informatics and Outreach (OBIO) established a DSS Steering Committee—a cross-section of headquarters and science center technologists and scientists—to plan for such a workshop.

This planning activity tied in nicely with the concurrent implementation of the USGS Decision Support System Special Interest Group (DSSSIG), and, in the spirit of cooperation as well as cost considerations, several activities of the two groups were combined. First, a DSS web page was developed. Next, an interactive questionnaire was posted to determine current USGS uses of and needs for decision support systems (Appendix A). Both the web page and the questionnaire proved to be useful tools for the DSSSIG and the BRD Decision Support System Steering Committee.

Through teleconferencing, the steering committee set the agenda for the workshop, in large part from the results of the questionnaire incorporated with other BRD interests. The workshop was sponsored by OBIO and was hosted by its Center for Biological Informatics (CBI) in Denver, Colorado. Approximately 55 persons attended, representing the Department of the Interior (DOI); the USGS Biological Resources, National Mapping, and Water Resources Divisions; and the U.S. Fish and Wildlife Service (Appendix B).

The format for the 3-day workshop included plenary presentations by BRD and U.S. Fish and Wildlife Service personnel who use decision support systems; breakout sessions addressing DSS technical information aspects, outreach/customer requirements, and future perspectives; and a DSS Steering Committee meeting to evaluate workshop goals and to provide guidance for future efforts. Steering committee action items developed from workshop inputs were to (1) develop a "DSS framework" document for use in biological research, (2) develop a "proof of concept" DSS based upon the framework document, and (3) integrate decision support systems into BRD program elements.

All three areas were addressed: integration of decision support systems into BRD program elements is currently in the draft stages, the framework document is targeted for publication in early 2000, and a prototype DSS will run through June 2000. The framework report (D'Erchia et al., in review) provides the characteristics and functionality of decision support systems and suggests generic steps for research and development of decision support systems. It stresses the importance of a team approach in developing a DSS, with early interaction among upper management, users, and system developers. Development of user-friendly interfaces is stressed to ensure that the DSS will be effectively used for its intended purpose. This biological framework for DSS development and use will help the biological community work together in achieving mutual goals. In addition, the BRD has launched a DSS web site at http://biology.usgs.gov/dss/ containing current information on DSS activities.

Editor's Note: The proceedings follow sequentially as they were presented at the workshop. As with any meeting, verbal presentations were more extensive than the abstracts provided here.

Literature Cited

D'Erchia, F., J. Getter, C. Korschgen, R. Root, R. Sojda, and P. Stine. Defining, developing, evaluating, and applying decision support systems: an ecological framework. U.S. Geological Survey, Reston, Va. In review.

Workshop Summary

On the first day of the workshop, participants spoke about the USGS vision, mission, and strategic direction. The BRD mission and the goals and objectives of the strategic plan were reviewed. In addition, the group looked at the goals of the National Biological Information Infrastructure (NBII) and discussed why both the USGS as a bureau and BRD as a division are interested in decision support systems. A cursory analysis of the DSS questionnaire responses was reported.

As a starting point for discussion, the DSS Steering Committee defined decision support system as: "The combination of data, information, and computer and non-computer based tools and services within a structured framework that can improve both the process and outcomes of decision making. Explicit recognition of the procedural component—that is, the decision making process—is as important as the analytical component—databases, geographic information systems, and models."

Why We Are Here: Framing the Questions

Ken Williams, USGS BRD, Chief, Cooperative Research Units

In his introduction, Williams addressed decision support systems in relation to content and context. He noted that decision support systems are heavily information oriented—not simply a data structure nor a temporal characterization of ecosystems. He also pointed out that a DSS is not necessarily continental nor global in scale, nor necessarily "research" per se: a DSS sustains linkages between management and information. The future vision of DSS attributes includes models linking landscape structures with biological attributes that overall should be based on thematic data. Williams noted that we should think about user interfaces—it is not enough to think only about computer and technological interfaces. A DSS relies on high-tech hardware, software, firmware, and data. The need for computer architectures that include data organization, data visualization, and modeling was stressed, and he noted that place-based logic should be incorporated into a DSS. Important points to consider:

- Who are the customers of the application?
  - How are they using the information?
  - How do they benefit from the application?
- What are the technical features of the application?
- Where is BRD in terms of DSS technology?
- Where do we need to go with DSS?
  - What direction should we take to get there?
  - What would it cost and how long would it take to deliver?
  - Who should benefit from it?
  - How would it fit into the programmatic context of USGS/BRD?

Keynote Address

Tom Gunther, Department of the Interior, Office of the Secretary

In his keynote address, Gunther provided perspectives on DSS tools, services, and systems. He addressed recent activities such as the interagency group on decision support systems, the USGS special interest group, and the Aurora Partnership. The Aurora Partnership is a collaboration of public and private decision support efforts. Aurora is focused on stimulating the development and application of the next-generation decision support systems that will enable the practical use of natural and social science in decision making. An open, collaborative process that builds on existing efforts in defined geographic regions (e.g., ecoregions, watersheds, counties) is their approach. See http://www.aurorapartnership.org. He spoke of emerging opinions related to DSS:

- Technology is not a constraint.
- Individual budgets and expertise are inadequate.
- We need cooperative development.
- There is a need to incorporate the concept of "plug and play."
- There is a need for interoperability, modularity, and World Wide Web connectivity.
- There is a need for a suite of tools, including services.

He related changing perspectives such as:

- Science needs input from decision makers, specialists, and stakeholders.
- Scientists must buy into DSS technology and process: there is a need for integration, information, functional relationships, and knowledge of databases and models.
- There is a broad need for a combination of DSS tools. Many development efforts are currently under way, many partnerships already exist, but there are gaps in DSS capabilities.
- There are gaps between scientific information and decision makers and processes.
- There are differences between technological feasibility and community capability.
- There are needs for single-purpose and integrated tools.

Workshop Presentations

Case Studies

A Resource Management Decision Support System for the Upper Mississippi River

Carl Korschgen, Norman Hildrum, Linda Leake, Carol Lowenberg, Doug Olsen, Hank DeHaan, Jason Rohweder,
USGS Upper Midwest Environmental Sciences Center;
James Nissen, Lara Hill,
U.S. Fish and Wildlife Service

In 1986, Congress recognized the Upper Mississippi River (UMR) system as both a nationally significant ecosystem and a nationally significant commercial navigation system. In doing so, Congress then directed the development of the Long Term Resource Monitoring Program and the Computerized Inventory and Analysis System. The monitoring effort has reached the point where significant amounts of scientific data have been collected, reviewed, and are now available to resource managers and decision makers. During recent years, we have concentrated our automation and spatial analysis efforts on developing tools and information distribution mechanisms that resource managers, scientists, and decision makers can use.

The process of building a biological decision support system (DSS) for the UMR has been a highly effective approach for communicating with our customers and identifying research and management needs. Our digital DSS has become an "electronic ecosystem encyclopedia" that planners and managers can use on a daily basis in making decisions regarding spatial and temporal conflicts and to generate a variety of products for agency use and public education. Our decision support system helps provide a long-term legacy for our science.

Customers/cooperators of this USGS program are the U.S. Fish and Wildlife Service, National Park Service, U.S. Army Corps of Engineers, Natural Resources Conservation Service, U.S. Environmental Protection Agency, five UMR states (Illinois, Iowa, Minnesota, Missouri, and Wisconsin), the Upper Mississippi River Basin Association, and numerous other public and private associations, organizations, and alliances. Our DSS provides the following capabilities to our customers/cooperators for their use during a wide variety of tactical and strategic management and planning efforts [specific examples were provided in the verbal presentation]:

1. *Mapping* – The ability to produce maps of single or multiple combinations of data at various spatial scales.
2. *Quantification* – The ability to determine numerical summations of various data elements within a particular mapped area.
3. *Graphical Display* – The ability to produce scientific tables, charts, and graphs of various sets of data.
4. *Modeling* – The ability to allow decision makers to "model" data to help address specific management issues.

Our DSS provides for an integrated, ecological, and proactive scientific approach to management of UMR resources. Decisions are more strongly supported when they are science-based rather than based on the intuition and perception ("art-based") of an individual manager. The DSS framework provides for an adaptive management approach to decision making and project evaluation. The partnership has identified data gaps and focused research projects to provide specific information on habitat requirements and for development of multiagency management alternatives.

The DSS has been an effective information visualization and integration tool to educate members of Congress, Federal and state agency leaders, and the public on the value and needs of the UMR system. Program scientists within all customer/cooperator agencies are incorporating more than 20 years of interagency environmental monitoring and research data into a common DSS platform.

Our approach has been to provide information, technology, and training to our customers/cooperators along a continuum that is best expressed as an inverse relationship between the ease of use and functionality of several software platforms. We have standardized on ESRI (Redlands, California) geographic information systems (GIS) software (ARC/INFO, ArcView, MapObjects) and are developing Internet-based (Java software) applications for serving spatial information. The Upper Midwest Environmental Sciences Center web site, which received more than 1 million visits in 1997, offers more than 8,200 files on fish, vegetation, macroinvertebrates, water quality, water levels, aerial photography, satellite imagery, scientific publications, and GIS data. Site-specific biological and physical information is routinely added to the DSS platforms by users.

BEST: The Biodiversity Expert System Tool

Patrick Crist, USGS Gap Analysis Program

Land-use development is a leading cause of species and habitat loss. Because local governments regulate most land use and are responsible for most of the land area in the United States, they play a critical role in either the destruction or conservation of our Nation's biodiversity. While state statutes may require consideration of biodiversity in local land-use planning and regulation, local governments lack access to the data, resources, and expertise to routinely consider biotic impacts from permitted land uses. USGS Gap Analysis Program (GAP) cooperators have developed a biodiversity expert systems tool—BEST—that uses GAP and other biological data in a desktop geographic information systems (GIS) environment to address this problem.

The BEST system gives planners access to more information than was previously available. For example, early in the process of assessing a development proposal, a BEST user (planner) selects a tract on the computer screen and then selects the proposed land use. The system walks the planner through the process of reporting the species and plant communities mapped or predicted for the tract and the type and degree of impact likely to occur. It also provides the ability to overlay other types of maps, generate reports, view documents on how the data were developed, and most importantly, it provides mitigation recommendations.

The system does not replace good, comprehensive planning or field confirmation of the results, nor can it operate in a vacuum without a solid foundation of regulations and citizen support for maintaining the community's natural heritage. But it is a useful tool to provide immediate expert knowledge to a planner—without requiring knowledge of GIS or biology. When used properly, BEST can aid a planner and development applicant in designing a project that is compatible with a parcel's native plant and wildlife species.

Across Trophic Level System Simulation (ATLSS): Integrating Predictive Models into the Decision Process

Donald L. DeAngelis, USGS Florida Caribbean Science Center

The Across Trophic Level System Simulation program, or ATLSS, is an integrated set of computer simulation models representing the biotic community of the Everglades/Big Cypress region and the abiotic factors that affect it. At present, primary funding for the program is from the Department of the Interior Critical Ecosystems Studies Initiative. Additional funding is coming from the U.S. Army Corps of Engineers (USACE), the U.S. Environmental Protection Agency, and the South Florida Water Management District.

ATLSS has both short- and long-term objectives. In the short term, ATLSS is providing scientific assistance to the Central and South Florida Comprehensive Review Study, headed by the USACE. It is providing this help by producing model predictions concerning the effects of alternative water management scenarios on key Everglades biota. ATLSS has played an important role in choosing a restoration plan for the Everglades; the decision on such a plan was made by the USACE in June 1998. Over the longer term, ATLSS models will be used along with monitoring of populations in the field to help in the adaptive management of the Everglades system as this plan is implemented.

The ATLSS models are spatially explicit, using geographic information systems map layers of topography, soil, vegetation type, and other data. The spatial extent of the models is the entire Everglades/Big Cypress region and some surrounding areas, and the spatial resolution is generally 500- × 500-meter cells, though sometimes finer. Relevant abiotic qualities—currently and primarily hydrology—are modeled. The biotic community is represented by a hierarchy of models, beginning with the process models of the biota constituting the energy base, including vegetative biomass, lower trophic level invertebrates, and decomposers. Models that contain some relevant detail on size and age structure simulate several important functional groups such as fishes, macroinvertebrates, and small reptiles and amphibians, which utilize the energy base and provide food for some of the top consumers. Several individual species that are highly valued because they are unique or threatened or are regarded as indicators of the overall conditions of the ecosystem are modeled in much greater detail, using individual-based models. Species include the American alligator, the American crocodile, several species of wading birds, white-tailed deer, the Florida panther, the Cape Sable seaside sparrow, and the snail kite. Model output is presented in a form that facilitates comparison of alternative proposed plans.

Decision Support Systems for Conservation Planning: A Prototype

Peter Stine, USGS Western Ecological Research Center;
Rick Church, University of California–San Bernadino;
Mike Gilpin, University of California–San Diego;
Ross Gerrard,
National Center for Ecological Analysis and Synthesis

Conservation planning for plants, animals, and natural communities over sizable geographic areas is an increasingly important focus of natural resource managers. In particular, Habitat Conservation Plans (HCP's) are being used to provide for conservation of threatened, endangered or sensitive species during land-use planning efforts. Effective conservation planning, however, requires synthesizing large amounts of scientific and socioeconomic information to make the best possible management decisions. This task can be greatly assisted by the development of comprehensive techniques that use new geographical analytical tools. Many current analytical systems are highly useful tools for organizing and viewing information but provide no quantitative means for decision making, nor do they incorporate cost factors into decision-making processes. The next generation of such tools involves the incorporation of models to allow managers to ask "what if" questions, predict the consequences of potential management actions, and identify optimal management strategies.

This project is still in the research and development phase. The anticipated customers/cooperators of this program are the U.S. Fish and Wildlife Service, state fish and game agencies, local (county, city) governments, and a wide variety of land-planning entities.

An important feature of the approach is that managers can select the parameters—e.g., the cost, amount, location and quality of habitat—that are relevant to each management situation. Furthermore, managers can select the relative values of each factor to evaluate different scenarios. Ultimately, we believe that the technique will be of great value in habitat conservation planning by empowering analysts to explore a wide range of alternative scenarios for land allocation. This approach will be especially valuable for resource management agencies as well as other groups that engage in developing HCP's and other types of land conservation strategies.

Through a collaborative effort supported by the National Center for Ecological Analysis and Synthesis, the U.S. Geological Survey (USGS) Biological Resources Division is developing computer techniques to explore and evaluate alternative habitat conservation strategies. These techniques use a geographic information system (GIS) to depict the landscape requirements for conservation of any given species. Like many such GIS models, this technique identifies and ranks species habitat; what makes it unique is a modeling feature that selects the optimum mix of lands to support the species in question while weighing various biological and socioeconomic factors.

This joint effort between the USGS and academia set out to push the frontiers of decision support system development by integrating GIS and optimal decision making. Our goal is to develop more scientifically sound methods and to create more useful tools for accomplishing conservation and management goals.

Adaptive Decision-making in Migratory Bird Management

Fred A. Johnson, U.S. Fish and Wildlife Service, Office of Migratory Bird Management

The pressure on migratory bird managers to make good, effective decisions is intense, despite the reality that the consequences of most management decisions are highly uncertain. This realization suggests that management should be treated more as an adaptive learning process, where there is an explicit accounting for uncertainty as well as a strong focus on its reduction.

An adaptive decision-making approach has been used in the Federal regulation of duck harvests since 1995 and involves an effort to balance short-term hunting opportunities with the long-term benefits of understanding how populations respond to harvest. The distinguishing features of adaptive harvest management are (1) concise and unambiguous management objectives; (2) a limited set of regulatory options; (3) a set of alternative models that capture key uncertainties about population dynamics and the effects of management; (4) a measure of reliability for each alternative model, expressing the relative confidence that it adequately describes population dynamics; and (5) monitoring programs used to recognize resource status.

Each year, an optimal regulatory option is identified based on resource status and the relative confidence in the alternative models. After the hunting season, monitoring permits a comparison of predicted management responses with those that actually occurred, enabling managers to eventually identify the most appropriate model of population dynamics. This conceptual framework is now being extended to include the management of migratory bird habitats. The institutional challenges are more formidable than in harvest management, however, and include balancing management objectives among a variety of species and coping with a highly fragmented decision-making process. From a technical perspective, perhaps the most difficult challenge will be the development of cost-effective programs to monitor landscape conditions at various spatial and temporal scales, and to discern their influence on migratory bird abundance. Used in the context of adaptive management, this monitoring and assessment information will ensure improved management of national wildlife refuges and other public lands, along with more effective strategic planning and evaluation of the North American Wetlands Conservation Act, the North American Waterfowl Management Plan, the Neotropical Migratory Bird Conservation Plan, and other large-scale avian conservation efforts. The U.S. Fish and Wildlife Service currently is working with the U.S. Geological Survey to meet these critical information needs.

Geospatial Project Summaries

Development and Pilot Application of the California Urban and Biodiversity Analysis (CURBA) Model

John Landis, University of California–Berkeley; Peter Stine, USGS Western Ecological Research Center

Conversion of wildlands to urban uses has had a significant and growing impact on conservation of biological diversity. In addition to consuming habitat, urban growth reduces the integrity of remaining habitat. A major share of the responsibility for conserving natural habitats, albeit indirectly, rests with local governments with land-use authorities. These agencies rarely have access to the data or the tools necessary to analyze the short- and long-term effects of land-use decisions.

The California Urban and Biodiversity Analysis (CURBA) Model was developed as a tool for constructively addressing these issues. The CURBA Model was designed to help bridge the gap between urban land-use planners, who are principally concerned with directing urban growth—and conservationists and resource managers, who are concerned with promoting environmental and ecological quality. The CURBA Model integrates three sets of data sources and modeling approaches that heretofore have been treated separately:

1. A statistical model of urban growth incorporating spatial and nonspatial components.
2. Procedures for simulating the effects of alternative development and conservation policies on the amount and pattern of urban growth.
3. Detailed and spatially explicit map and data layers regarding habitat types, biodiversity, and other measures of biological value.

To date, CURBA model datasets and equations have been developed for nine California counties, and additional datasets are under development.

The anticipated customers/cooperators of this program are the wide variety of land planning entities who have some mandate or interest in anticipating long-range impacts of land-use changes on ecological stability and conservation. Resource management agencies such as the U.S. Fish and Wildlife Service and state fish and game agencies should also have an interest in this tool/approach.

The CURBA Model, which is still in the research and development phase, represents a significant step forward in enabling policymakers and planners to project and evaluate the possible effects of alternative urban growth patterns and policies on natural habitat quality. The model achieves significant advances on three fronts. First, it allows planners, policymakers,interest groups, and residents to better understand the forces and factors behind recent urbanization trends and patterns. Second, it allows them to more easily project future urban growth patterns and to investigate the sensitivity of projected urban growth patterns to alternative regulatory and environmental policies. Last, by bringing together previously unrelated spatial data sources in a common framework, it allows policymakers, urban and environmental planners, wildlife ecologists, natural resources managers, and everyone else concerned with the future of the natural environment to constructively evaluate the effects of projected urban growth on habitat integrity and quality.

The policy simulation and evaluation component of the CURBA Model runs entirely in ArcView (ESRI, Redlands, California), which can serve as a robust simulation tool. A typical run of the CURBA Model makes use of a dozen grid layers, each of which commonly includes more than 1-million-hectare grid cells.

Running the CURBA Model—including generating maps and reports—typically takes less than 10 min per scenario.

VegSpec: A Revegetation Tool for Land Managers

David A. Pyke, USGS Forest and Rangeland Ecosystem Science Center

Land managers, whether private, state, or Federal, are often faced with difficult decisions on how to use plants in solving land management problems. Managers must determine the appropriate species and techniques to establish plants for revegetation, reclamation, or restoration of plant communities. Vulnerable lands need vegetation to protect them from erosion, to improve degraded wildlife and livestock habitat, to protect water sources from pollution, and to protect homes and farms from wind and snow.

Resource specialists are often contacted by the public or are assigned the task of determining the appropriate species and techniques to use for establishing plants that can withstand specific uses. Their recommendations are often needed quickly, but such information is not easily found. For example, Bureau of Land Management managers must provide detailed proposals for wildfire revegetation within 3 weeks after a fire is extinguished. As a result, they often do not have enough time to thoroughly research species or technique options. One solution to this problem is an expert system to help prescribe appropriate species and techniques for establishing plants.

VegSpec is a web-based expert system developed cooperatively by the U.S. Geological Survey, U.S. Army Corps of Engineers, and the U.S. Department of Agriculture Natural Resources Conservation Service. It is available to all land managers through a user-friendly platform on the Internet. Using a series of species selection rules relating to climate, soils, and specific uses, the VegSpec program queries three databases to match adapted plants with specific site conditions. These three databases are (1) the currently published NRCS soil surveys for all 50 states, (2) long-term monthly temperature and precipitation data for selected climatological stations in each of the 50 states, and (3) a plant database of more than 2,000 species with 70+ fields of growth and adaptation characteristics for each plant.

The VegSpec user is asked a series of questions related to the site description, including location (the state), soil mapping unit, and climatological station that describe the site. If the user does not have access to these data, a soil attribute and climate table must be completed. After describing the site, the user selects a series of objectives for revegetation such as rangeland plantings, forest products, erosion control, filter strips, landscaping, windbreaks, or pasture lands. Additional qualities such as wildlife habitat, trampling resistance, or fire tolerance also may be selected. Each objective and purpose has associated rules that select plants meeting those criteria. Thus, the user is provided with a list of potential plants that will establish, grow, and withstand the conditions and uses of the site. After species selection, the user is prompted to construct the planting design. VegSpec downloads a Java applet that contains spreadsheets for calculating seeding and planting designs. When this step is completed, the user may print a report describing the site and the selection process.

VegSpec users save time and money by quickly developing a planting design that will improve revegetation success through the selection of adapted plants for the site and for the desired uses. Users may access VegSpec with either Netscape or Internet Explorer version 4.0 or higher and a 28.8 bps or faster modem or Internet connection. VegSpec is reached through a link on the U.S. Department of Agriculture PLANTS web site at http://plants.usda.gov.

BRD Central Region Spatial Query System: Linking Geographic Locations of SIS Projects to Place-based Areas of Interest

Pete Bourgeois and Vince Sclafani, USGS National Wetlands Research Center, Gulf Breeze Project Office; James B. Johnston, USGS National Wetlands Research Center; and Frank D'Erchia, USGS Biological Resources Division Central Regional Office

Advances in remote sensing, geospatial technology, mapping, modeling, and computer simulation make it possible to employ computer-based approaches for resource management. The objective of the Central Region Spatial Query System (SQS) is to provide the information and tools necessary to geographically identify locations of important biological resources and the stakeholders and land management agencies involved in decision making critical to these resources. The goal is to assist U.S. Geological Survey (USGS) Biological Resources Division (BRD) managers and scientists in identifying place-based areas of importance to conduct research, monitoring, and other information synthesis activities that provide information to decision makers.

The SQS will provide an interactive link between the BRD's Science Information System (SIS) and a geospatial mapping program. SIS provides summaries of BRD projects and locations of study areas. ESRI (Redlands, California) ArcView software will be used to display geospatial data layers of the study areas; custom programs will be developed to link to the SIS and other regional and national databases.

The system will consist of a custom user interface developed in ArcView using standard programming tools. The primary view starts with a dataset of the U.S. state boundaries to orient users geographically. Three different ways to initiate a query are provided; all are available from the master pull-down menu: (1) the user can select from a list of all existing SIS account numbers; (2) the user can graphically draw a circle, rectangle, or polygon on the display screen, and the system will find all SIS projects located in the designated area; and (3) the user can utilize other base maps to query for SIS projects, such as state boundaries, USGS regions, National Park Service boundaries, or boundaries for several place-based ecosystems, such as the Greater Yellowstone Area. For example, if in using the state boundaries dataset the user narrows the selection to Colorado and Utah, the system will find SIS projects in these states. For all three query types, the system will find the appropriate SIS projects, zoom to and label on the screen the SIS account number, and (using the SIS account number) access the SIS web site through an automatic Internet connection, using a browser to display the appropriate SIS documents. The result is a very flexible system for spatially selecting SIS projects.

Although the ability to program the Internet link has been successfully evaluated, for our demonstration, SIS information will be stored in a local file resident on the computer hard drive. The demonstration will focus on the usefulness of geographically referencing SIS project locations to other geospatial information, such as agency and stakeholder boundaries and biological information (e.g., vegetation coverage).

The concept of linking databases to the SIS over the Internet could be expanded to other Internet-based databases, such as the U.S. Environmental Protection Agency's national databases (among others). Using commercial software, the system could be provided on a CD-ROM or served over the Internet.

The SQS utilizes the following datasets:

- AVIRIS flight lines for the United States, including Alaska.
- AVIRIS flight lines clipped out for the Central Region.
- The National Breeding Bird Survey (BBS), with mean counts for each bird species listed by American Ornithological Union number.
- BBS data clipped out for the Central Region.
- Congressional Districts for the 105th Congress taken from Tiger/Line data.
- Polygonal Federal lands at a scale of 1:2,000,000 from the USGS National Atlas database.
- Linear Federal lands at a scale of 1:2,000,000 from the USGS National Atlas database.
- Partners in Flight North American Ecoregions Map. Includes data for the lower 48 states, Alaska, and Canada.
- Partners in Flight ecoregions clipped out for the Central Region.
- ArcUSA data at a scale of 1:2,000,000, consisting of the following layers:
  - County boundaries
  - Federal lands
  - Lakes and other water bodies
  - Land/ocean display
  - Map elements Landsat nominal scene index
  - Place names latitude and longitude grids
  - Rivers and streams
  - Roads
  - Railroads
  - state boundaries
  - USGS 1:24,000 topographic quadrangle series index; USGS 1:100,000 topographic quadrangle series index; USGS 1:250,000 topographic quadrangle series index; state and county 1990 census, Public Law 94-171 data; state and county agricultural product inventory; state and county agricultural product market value; state and county demographic and health attributes; county environmental attributes; state and county government and financial attributes; and state and county socioeconomic attributes
- Landfill locations for the lower 48 states.
- U.S. Environmental Protection Agency reach file Version 1.0 (RF1) for the conterminous United States.
- Omernik's ecoregions for the lower 48 states.
- U.S. Army Corps of Engineers district boundaries for the continental United States.
- 1:2,000,000-scale hydrologic units of the conterminous United States.
- Digital map file of National Water-Quality Assessment Program.
- A geographic information system for tracking zebra mussels (*Dreissena polymorpha*) in the United States.
- Threatened and endangered species:
  - All taxa
  - Amphibians
  - Angiosperms
  - Animals
  - Arachnids
  - Birds
  - Clams
  - Crustaceans
  - Ferns

- Fish
- Gymnosperms
- Insects
- Mammals
- Plants
- Reptiles
- Snails
- National Park Service (NPS) park boundaries.
- The following regional boundaries for the lower 48 states, generated by using the ArcUSA county database:
  - American Fisheries Society regions
  - National Audubon Society regions
  - NPS regions
  - Natural Resources Conservation Service regions
  - National Wildlife Federation regions
  - Sierra Club field areas
  - The Nature Conservancy regions
  - U.S. Bureau of the Census regions
  - U.S. Environmental Protection Agency regions
  - U.S. Fish and Wildlife Service regions
  - U.S. Geological Survey regions
- Science Information System – SIS provides summaries of BRD projects and locations of study areas.

GIS-based Random Sampling Generator Module for Environmental Monitoring Program

Pete Bourgeois, Vince Sclafani, and Steve Robb, USGS National Wetlands Research Center, Gulf Breeze Project Office; Kevin Summers, U.S. Environmental Protection Agency, Gulf Ecology Division; and James B. Johnston, USGS National Wetlands Research Center

The U.S. Environmental Protection Agency's (EPA) Environmental Monitoring and Assessment Program (EMAP) and the U.S. Geological Survey (USGS) National Wetlands Research Center (NWRC) have been working with the Gulf of Mexico coastal states to help develop comprehensive strategies for monitoring surface water in each state along the Gulf of Mexico Coast. The methods used along the gulf are fundamentally similar, yet they are adapted to the specific needs of each state.

A successful transfer of EMAP technologies and approaches to create a comprehensive, integrated coastal monitoring program for Alabama was completed in 1998. Similarly, the Florida Department of Environmental Protection (FLDEP), in conjunction with the EPA and NWRC, designed a comprehensive water resource sampling strategy for Florida, scheduled to begin in 1999. Unlike Alabama's initial efforts, Florida desired to address all surface and groundwater resources simultaneously by using an integrated monitoring design (i.e., lakes, streams, estuaries, groundwater). This monitoring program will be used to provide data to satisfy Florida's Section 305b reporting requirements of the Clean Water Act. The program will also augment several state priorities, such as ecosystem management, establishment of water body assimilative capacity and total daily maximum loads, and permitting activities. This monitoring approach provides a way to ascertain the "health" of Florida's water resources by using probabilistic (random) sampling.

The state of Florida and its EMAP partners (EPA and USGS) developed an integrated, comprehensive monitoring design that can be used to characterize the conditions of the state's water resources. The sampling strategy targets 30 sampling locations for each resource using the following resource strata: (1) wadeable and nonwadeable streams; (2) lakes less than 10 hectares and lakes greater than 10 hectares; (3) confined and unconfined wells; and (4) estuaries, with a separate marine category. This strategy produces 1,350 total sampling sites per year across all resources and reporting areas and 6,750 sampling sites over the 5-year period. The following summarizes the monitoring program, or the geographic information system (GIS)-based random sampling generator module for Florida.

The state of Florida was divided into five Water Management Districts (WMD's) that were used as the primary strata for the sampling design. Each WMD was further subdivided into our reporting units based upon USGS 1:250,000-scale hydrologic unit codes, which were modified by FLDEP to correspond to 1:24,000-scale maps. The sampling strategy was designed for a 5-year period. One of the four reporting units within each WMD is sampled each year; additionally, one of the reporting units is randomly selected to be sampled twice, although not in successive years. The base maps were generated from USGS 1:100,000-scale digital line graphs (DLG's) for the canals, lakes, and estuaries. The streams were derived from EPA river reach files (RF3's), which were modified versions of USGS 1:100,000-scale hydrology DLG's. All of the datasets reside digitally in a GIS. Each of the four categories of hydrology (lakes, streams, estuaries, and groundwater) were compiled to correspond with the sampling regions. A series of programs and scripts written in Perl, UNIX csh, ARC/INFO macro language, and ArcView Avenue have been combined to create the random sampling generator (RSG) module, which runs in ArcView (ESRI, Redlands, California). The RSG module provides an efficient method to create probabilistically generated sampling locations based on specific resource design attributes, while maintaining a standard and recordable methodology.

Monitoring natural resources in an unbiased probabilistic and representative fashion can be a task requiring significant advance planning, especially if one is trying to do so over a large geographic extent. There is simply not enough time, money, staff, and other resources to sample "everywhere." In order to get meaningful and representative valid data, a probabilistic sampling scheme must be designed. By utilizing GIS and our RSG module, production of a more efficient and standard methodology to generate probabilistic sampling locations for water resource monitoring programs is possible. In addition, the GIS provides maps of the resources with the appropriate latitude and longitude for each resource's sampling stations, allowing field crews with Global Positioning System capabilities a more proficient method of locating the appropriate sites for collecting the necessary field data. GIS and RSG have aided the primary goal of obtaining as much information as possible in a cost-efficient and timely manner for production of the data needed to characterize the different water resources.

Oyster Lease Litigation Decision Support–GIS

John A. Barras, USGS National Wetlands Research Center, Coastal Restoration Project Office and James B. Johnston, USGS National Wetlands Research Center

The U.S. Geological Survey (USGS) National Wetlands Research Center (NWRC) has developed a decision support–GIS to assist both the Louisiana Department of Natural Resources (LDNR) and the Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA)Task Force in assessing potential oyster leasing conflicts related to coastal restoration activities. The CWPPRA Federal/state Task Force and LDNR are actively involved in a long-term (over 10 years) effort to restore Louisiana's coastal wetlands. Many active and planned restoration projects are located in oyster-producing waters, requiring planning to determine where the oyster leases are located and how many leases are either adjacent to or within potential restoration project areas.

State water bottoms are leased to oyster fisherman for a period of 15 years by the Louisiana Department of Wildlife and Fisheries (LDWF). Leases are frequently renewed for several 15-year cycles if they are located in a productive area. More than five lawsuits have been filed against LDNR and LDWF that are related to alleged detrimental impacts due to coastal restoration projects, particularly freshwater diversions. Long-term oyster leasing impact assessments have become mandatory to reduce potential coastal restoration-related resource conflicts. The decision support–geographic information system (GIS) developed by the NWRC with LDNR and the CWPPRA Task Force provides a valuable planning and impact assessment tool.

The decision support–GIS uses up-to-date LDWF oyster leasing information to assess potential leasing conflicts. LDWF data consist of lease owner and lease information stored in an Oracle database, and surveyed lease boundary information is maintained on an individual 7.5-minute USGS quadrangle base and stored in an Intergraph DGN format. The data from LDWF, although positionally accurate, are in a format that does not allow rapid spatial assessment of oyster lease information on a coast-wide basis. Therefore, the LDWF data are converted to an ARC/INFO (ESRI, Redlands, California) format and are merged to form a contiguous coast-wide oyster lease database suitable for localized or regional spatial analysis to assess potential restoration project conflicts and impacts.

The NWRC has also developed a "restricted area" polygon ARC/INFO dataset to identify areas where potential restoration project/oyster lease conflicts will occur. This "restricted area" is a dynamic dataset consisting of (1) CWPPRA restoration project locations, (2) Water Resources Development Act project boundaries, (3) state wetland restoration project boundaries, (4) state and U.S. Army Corps of Engineers dredge disposal site locations, and (5) freshwater diversion impact areas. The restricted area dataset is updated on a yearly basis and is used in conjunction with the LDWF information to eliminate the placement of new oyster lease applications within restricted areas and to ensure that renewal leases are not located within restricted areas. Renewal leases are reviewed to determine if a "bobtailed" short-term renewal is feasible, depending on lease location.

Current decision support–GIS applications:

1. *New Oyster Lease Application Assessment* – minimizes new oyster lease applications in areas where restoration project impacts either will or may occur so that potential liability may be reduced.
2. *New Restoration Project Siting Assessment* – limits potential restoration project siting conflicts in areas with high oyster lease concentrations. Allows estimation of leases within or adjacent to proposed restoration projects.
3. *Expiring Lease Assessment* – allows determination of potential conflicts with existing leases up for a new 15-year renewal. Leases located within "restricted areas" can be renewed for a bobtailed lease term that allows renewal for a one- or two-year term, depending on the restricted area.
4. *Restoration Project Realty Planning* – allows assessment of potential oyster lease impacts during

restoration project construction (e.g., access for dredges).

5. *Oyster Lease Lawsuits* – provides a useful analysis tool for assessing claimed damages.

The oyster lease decision support–GIS is a dynamic decision analysis system that requires input from a variety of state and Federal agencies to maintain required data currency. The availability of the decision support–GIS has saved the LDNR and the CWPPRA Task Force thousands of hours that would have been required to provide lease impact assessments using paper maps and hard-copy lease permit documentation.

Louisiana Internet and Desktop Oil and Gas Well Information Systems

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Louisiana Internet Well Reference

The Louisiana Internet Well Reference (LIWR) is a cost-free link to oil and gas well information housed by the Louisiana Department of Natural Resources (LDNR). It provides a means for obtaining oil and gas well information that can be used to access the Louisiana Energy Access System, which provides dial-in service to the LDNR's entire oil and gas database. Information from the system can also be used to research the hard-copy files at LDNR or Office of Conservation district offices. The data offer a "current record" of more than 200,000 oil and gas wells, which are accessed with a graphical geographic information system query tool. Some records, however, cannot be accessed due to lack of or errors in locational data. Missing or incorrect data will be gradually added to or corrected in the database and will subsequently be made available through the LIWR.

The LIWR was developed using ArcView Internet Map Server software (ESRI, Redlands, California). The three base maps include a parish boundary map and two U.S. Geological Survey (USGS) digital raster graphics maps at a 1:500,000 and a 1:100,000 scale, and well locations can be referenced to natural and cultural features and boundaries. Well locations are shown as derrick symbols and can be identified by using the "id" tool and by selecting the desired well. This action displays a table of the data related to the specific well. The user can also display the well status/product symbols used by the Office of Conservation by activating the "lightening bolt" tool and selecting a well. Other important features are "zoom" and "pan." Users can view instructions for using the LIWR, including printing.

The data from the "current record" database displayed for each well includes the well serial number (generated by the LDNR), API number (generated by industry), well name, operator name, total depth, perforation depths, location (section, township, range, and coordinates), current status, and other data related to the well.

The LIWR was developed by the Louisiana Department of Natural Resources by the Office of Conservation's Geological Division, the Office of Management and Finance's Information Services Division, and the USGS National Wetlands Research Center (NWRC), which created the majority of the software under a cooperative agreement.

Louisiana Desktop Well Reference

The Louisiana Desktop Well Reference (LDWR) is a "point-and-click" spatial display and query system consisting of several custom programs and datasets. It allows users to easily access both spatial and attribute information for Louisiana oil and gas well and ancillary datasets.The LDWR is an in-house system used by LDNR and NWRC analysts to determine potential conflicts between oil and gas industry and other coastal activities such as coastal wetlands restoration projects, navigation, commercial fishing, protection of endangered and threatened species, recreation, flood protection, and urban expansion. The LDWR allows users to review Section 404 wetland permits, plan Coastal Wetlands Planning, Protection and Restoration Federal/state Task Force restoration projects, prepare the Coastal Comprehensive Management Plan for the Barataria/Terrebonne National Estuary Program, and review oil and gas exploration and production activities.

The NWRC has assisted the Louisiana Department of Natural Resources with all aspects of the LDWR system, including development, programming, training, and enhancements using ArcView.

Wetlands Reserve Program Decision Support System

Steve Hartley, USGS National Wetlands Research Center; Antonio Martucci, Johnson Controls World Services, Inc.; and James B. Johnston, USGS National Wetlands Research Center

In the last century, the Lower Mississippi River Valley has experienced dramatic forested wetland losses (over 80%) as a result of clearing for agriculture and urban expansion. Federal and state efforts promote wetlands conservation and restoration programs that preserve these valuable resources for future generations.

Advanced spatial analysis techniques such as decision support systems and geographic information systems (GIS) improve the resource manager's ability to define potential sites for wetland restoration or conservation. Partners in developing the Wetlands Reserve Program (WRP) Decision Support System are the U.S. Department of Agriculture Natural Resources Conservation Service (NRCS), Alexandria, Louisiana; the U.S. Fish and Wildlife Service Ecological Services Office, Lafayette, Louisiana; The Nature Conservancy, Baton Rouge, Louisiana; and the U.S. Geological Survey National Wetlands Research Center, Lafayette, Louisiana.

The WRP is a voluntary program to restore and protect wetlands located on private property. The program is administered by the NRCS, in consultation with the Farm Service Agency and other Federal agencies. Participating landowners receive financial support to take their marginal agricultural land out of production for conversion to wetlands or to enhance or protect existing wetlands. The ultimate goal of the WRP is to enroll approximately 405,000 ha (1 million acres) nationwide. The states of Tennessee, Louisiana, Mississippi, and Alabama will benefit most from this program.

Using ArcView 3.0a GIS software (ESRI, Redlands, California), we developed an application to organize the available datasets and allow land resource managers to access sophisticated display and analysis tools without being GIS experts. ArcView, combined with Avenue scripting language, offers the possibility of integrating and visualizing geographic and tabular data into a complete analysis system, while creating a highly user-friendly Windows (Microsoft, Redmond, WA) environment. This achievement was considered a primary goal because we have found that GIS is rarely used because of its prohibitive costs (hardware and software) and learning curve.

ArcView Graphical User Interface (GUI) has been customized for this project using menus and menu items, as well as added buttons and tools. Land resource managers can access sophisticated display and analysis tools without being GIS experts. The GUI also allows the user to select information layers, open display windows, and perform some complex and multiphase tasks in one or more steps. Input and selection message boxes guide the user to complete processes successfully.

GIS is a technology that allows the assembly, storage, manipulation, display, and output of geographical and related tabular data. Investigations and analyses of different but geographically related datasets may be performed by using overlay or query techniques. Additionally, GIS can use different types of data and information from different sources and in different forms. The primary purpose of a GIS application is to present geographic and tabular data in one comprehensive, easy-to-use application. This WRP application incorporates those capabilities, allowing the user to better utilize and analyze incoming environmental data with existing datasets.

"Smart" Reference/Expert Systems for Data Mining Project Summaries

WILDPro Multimedia: A Different Way of Finding Information

F. Joshua Dein, USGS National Wildlife Health Center

Professionals frequently need rapid access to a wide range of reference information to solve an acute problem, but they do not have time for an exhaustive search of—nor access to—needed printed materials. In addition, many situations require knowledge of facts and procedures in fields ancillary and remote to one's own, which makes information retrieval for decision making more difficult. While both online and library or CD-ROM-based databases may contain these details, accessibility and ease of use limit their benefits in many instances.

To address this situation, WILDPro takes an innovative approach to information access by offering a broad range of technical information in text and image form, which are all hyperlinked to allow information to be found through different entry points and paths. Links are provided to ensure that important related data are highlighted. Procedural flow-charts are also available to guide searchers though complex and/or unfamiliar tasks. A demonstrator version of WILDPro has been produced, illustrating the concept as it applies to wildlife health. It contains sections on species biology, infectious and noninfectious agents, environmental factors, and disease conditions. Areas containing geographic, institutional, commercial, and bibliographic data are also included. For example, if a refuge manager is presented with a waterfowl mortality event, he or she could use WILDPro to access the flow chart on disease investigation, obtain information on diseases commonly found in the species affected, analyze the conditions that may have led to the event, and plan a mitigation strategy. Links to institutions that could provide support and consultation would also be available. This information would be found through sequential hyperlinks that lead the user to the appropriate reference material.

The complete program is currently under development, and a discipline-specific module should be ready in 12–18 months. WILDPro has an open architecture created with World Wide Web languages and can serve as an interface with preexisting databases. While originally planned as a wildlife health manual, its generic structure and programming will also allow it to be used in many other fields and applications:

1. Users: wildlife professionals (biologists, managers, veterinarians).
2. Information use: on-site access to a broad range of discipline-specific data.
3. Benefits: rapid retrieval, query language not required, and easy access to related subject data.
4. Structure: open, generic architecture; text/graphics pages connected through hyperlinks.

Designing a Data Warehouse for Energy and Environmental Data Sources

Judy Buys, U.S. Geological Survey, National Wetlands Research Center; Vijay Raghavan and Pavani Kuntala, Center for Advanced Computer Science, University of Louisiana

In 1997, under the umbrella of the Department of Energy's Energy and Environmental Technology Applications Program, the University of Louisiana (UL) received "Information Systems Technology for Energy and Environmental Applications" funding (DE-FG02-97ER12220) to develop a data warehouse consisting of selected environmental datasets. Three partners are participating in the project: the U.S. Geological Survey National Wetlands Research Center (NWRC) library, the Center for Advanced Computer Studies (CACS) at the University of Louisiana and the NASA/UL Regional Applications Center at CACS.

As part of this project, the Energy and Environmental Information Resources (EEIR) Center is being designed to manage and facilitate researcher and general public access to data and information sources pertaining to the Louisiana coast. However, these data are available in a number of different formats, and often the data are offered without application software and in very large files. Users who may need to extract only a few years of data from a large data library are faced with a number of separate databases, each with its own search interface. In addition, users may require assistance analyzing the data using software tools not readily available or using analysis tools such as geographic information systems (GIS), databases, or statistical application software packages that require specialized training or experience. Other problems are text formats that are not compatible or that need a specialized viewer or printer (e.g., PDF or PostScript files).

The research component of the EEIR Center is provided by CACS. Computer scientists at CACS address technical problems such as innovative ranking issues that discover patterns in the data, ranking algorithms based on user feedback, and data transfer and communications protocols needed between client and server to carry out ranking tasks. In addition, they are addressing the need for automated tools to support knowledge discovery from large databases based on the type of data mining query, concept-based retrieval, and adaptive retrieval based on relevance feedback. One research project is aimed at moving data from existing data sources into a data warehouse by using dimensional modeling and data warehousing tools. Our research methodologies involve retrieval of information from different sources on the Web, transformation of the retrieved data, and employing modern methods in developing decision support systems. The system design uses four steps:

1. Use image maps to query for information; the image maps provide World Wide Web access to geographically referenced datasets such as wetlands, water quality, and air quality data. Users are presented with an interactive map; by choosing a specific location on the map, users can query information from the region of choice.
2. Transform the retrieved data.
3. Use dimensional modeling techniques to store the queried information with the existing information in the data warehouse.
4. Analyze the data using applications software such as decision support and data visualization tools.

To assist users, the EEIR Center supports three librarians and a GIS specialist at the NWRC library. The librarians collect data and information on Louisiana coastal areas and organize and supply data and information sources in digital format. Data and information sources are described by using national metadata standards and are added to the EEIR Center Internet resources and databases of materials. In addition, metadata are added to WorldCat, an international bibliographic database; the National Spatial Data Infrastructure; and the National Biological Information Infrastructure servers.

Regional Application Centers were initiated by NASA Goddard Space Flight Center's Applied Information Sciences Branch. The centers collect realtime data from NASA satellites at regional institutions and allow users to customize the system for specific applications. Algorithms implemented at each Regional Applications Center provide a high degree of accuracy in mapping the satellite data to the regional geography within the service area and will be a source of data used at the EEIR Center.

A description of the EEIR Center and Energy and Environmental Technology Applications Program components, and a listing of metadata collected are available at http://eeirc.nwrc.gov.

Nonspatial Environment Project Summaries

PREDICTOX Estimates Acute Aquatic Toxicity from Chemical Structure

James P. Hickey, USGS Great Lakes Science Center

Thousands of chemicals are in use and thousands more of their byproducts and breakdown products are in the environment. Many more new compounds are introduced yearly. The physical property data needed to reliably estimate potential hazards—let alone perform accurate risk assessments—are available for only a small fraction of these compounds, and similarly, only a small fraction are regularly monitored for quantity of occurrence. Testing for a single toxicity data point can tie up 6–10 weeks of equipment and technician time and can cost $6,000–$10,000 for one test organism. The costs in terms of money, time, and personnel for developing the data needed for all compounds in use would be impossible to realize, resulting in an urgent need for a way to obtain reliable estimates of potential hazards. Predictive modeling efforts save time and money, and bridge data gaps. For example, the U.S. Environmental Protection Agency relies on predictive models almost exclusively for chemical registration procedures.

An interdisciplinary team at the U.S. Geological Survey Great Lakes Science Center developed expert system software (Hickey et al. 1990, 1992), designed around the elegantly simple structure–activity relationship LSER (Linear Solvation Energy Relationship) for contaminant property prediction and screening (Hickey 1996). Many chemical properties important for the understanding of environmental processes (solubility, toxicity, partitioning, chromatographic behavior, to mention a few) depend on a contaminant–medium (e.g., water or lipid) interaction, and LSER has shown much success in environmental applications (Kamlet et al. 1986). This predictive software system, the first based solely upon LSER, relies on literature toxic endpoint data with proper quality assurance and quality control for (at present) estimation of organism toxicity to new compounds under specific conditions. A chemical structure input as a SMILES string is translated into LSER values, which then predict the acute (baseline) toxicities for the Microtox test, *Daphnia pulex*, *Daphnia magna*, and the fathead minnow (*Pimephales promelas*). Current developments, when incorporated, will enable recognition of nonnarcotic modes of action and predict other physical properties. The software will also be one of the few methods that will estimate the environmental properties of inorganic species.

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Multicriteria Decision Support System for Bureau of Reclamation Reservoir Operations

Zachary H. Bowen, Ken D. Bovee, and Terry J. Waddle, USGS Midcontinent Ecological Science Center

The Upper Missouri River Decision Support System was developed to help Bureau of Reclamation reservoir operators evaluate the effects of different reservoir operations scenarios on a variety of water-related resources.

In this decision support system, Reclamation's Reservoir Operations Modeling System (ROMS) is linked by a simple Visual Basic program to Excel spreadsheet modules designed to evaluate power production, flood control benefits, irrigation water deliveries, municipal and industrial water supplies, habitat for endemic fish communities, tailwater fisheries, nesting habitat for shorebirds, reservoir recreation, reservoir fisheries, and regeneration of riparian cottonwood forests. Operation scenarios generated in ROMS are scored for each decision variable by way of an ordinal index. Scores are derived by determining a target window (e.g., gigawatt hours of electrical power production or acre-feet of water delivered for irrigation) for a reference location and time period. The score for a variable is calculated based on the ratio between the percent of time that target conditions are met under alternative operating conditions and under the reference condition, respectively. One unique characteristic of this scoring technique is the recognition that under either natural or highly managed conditions the reference target is not met at all times. Another characteristic of this approach is that higher scores are achieved for environmental decision variables by maintaining natural seasonal and annual variability in discharge and habitat availability.

DSS: A Brief Historical Perspective

Mike P. Mulligan, USGS Center for Biological Informatics

At the outset of a discussion about decision support systems (DSS) in the U.S. Geological Survey Biological Resources Division, it is appropriate to examine their evolution in a broader context; that is, the history of the decision support concept. This discussion will attempt to briefly do that. I will touch on the origins and evolution of decision support systems in the information science and management fields, pointing out that while the terms "GIS" (geographic information systems) and "DSS" are not exclusionary, they are also not one and the same.

By highlighting some of the historical DSS definition mainstays, I will focus on the frequency of ill-defined problems and the need for flexibility, as well as the hierarchial nature of DSS design. In addition, I will point to developers of natural resources-focused DSS/ knowledge-based systems, both in the United States and abroad.

"Gray Literature" Origins and Themes

- 1940's to 1950's: World War II British operational research.
- Location-allocation problems.
- Heuristic and linear programming models.
- Search for automated tools to supply value-weighted data and interpretation to decision making and to document and legitimize the decision-making process.
- Some major contributors (late 1960's to early 1980's):
  - R.H. Sprague
  - S. Morton
  - P.G.W. Keen
  - R. Bonczek, C. Holsapple, and A. Whinston
- Focus on ill-defined or unstructured problems; nonroutine, one-of-a-kind answers, if undertaken later, may produce differing result.
- Computer-based emphasis on ill-defined, unstructured, or semistructured questions; not automating structured decisions, interactive interface/human–computer interface, and iterative ("what if" functionality).
- Front-end to many data sources that decision makers can use: database management systems, geographic information systems, and lower-level DSS.

Starting Point Definitions of Decision Support Systems

- The combination of data, information, and computer and noncomputer-based tools and services within a structured framework that can improve both the process and outcomes of decision making. Explicit recognition of the procedural component—that is, the decision-making process—is as important as the analytical component, databases, geographic information systems, and models.
- Decision support systems are computer-based programs and technologies designed to make routine decisions, monitor and control processes, and aid or assist decision makers in semistructured and/or nonroutine decision situations.
- Decision support systems are interactive computer-based systems that help decision makers use data and models to identify and solve problems and make decisions. The "system must aid a decision maker in solving unprogrammed, unstructured (or 'semistructured') problems . . . . [It] the system must possess an interactive query facility, with a query language that . . .is . . .easy to learn and use" (Bonczek et al. 1981). Decision support systems help managers/decision makers use and manipulate data, apply checklists and heuristics, and build and use mathematical models. According to Trippi and Turban (1990), a DSS has four major characteristics: (1) it incorporates both data and models, (2) it is designed to assist managers in their decision processes in semistructured or unstructured tasks, (3) it supports, rather than replaces, managerial judgment; and (4) its objective is to improve the effectiveness of the decisions, not the efficiency with which decisions are being made.

Glossary

Unstructured decisions. An unstructured decision situation is complex and no standard solutions exist for resolution. Some or all of the structural elements of the decision situation are undefined, ill-defined, or unknown. For example, goals may be poorly defined, alternatives may be incomplete or not comparable, choice criteria may be difficult to measure or difficult to link to goals.

Domain expert. A domain expert is a person who has expertise in the domain in which a specific expert system is being developed. A domain expert works closely with a developer (known as a knowledge engineer) to capture the expert's knowledge (especially rule and relationship information) in a computer-readable representation often called a "knowledge base."

Group decision support systems. Group decision support systems are interactive, computer-based systems that facilitate the solution of unstructured problems by a set of decision makers working together as a group. This type of DSS aids groups, especially groups of managers, in analyzing problem situations and in performing group decision-making tasks.

These definitions are used with permission from Power, D.J. 1999. Decision Support Systems Glossary. Decision Support Systems Resources. World Wide Web http://dssresources.com/glossary.

Spatial Decision Support Systems

Spatial decision support systems (SPDSS) are based on the above progenitors but also incorporate the special requirements of spatial data. The following individuals are recognized SPDSS progenitors:

- Gerard Rushton, University of Iowa
- Paul Densham, London
- Mark Armstrong, University of Iowa
- Mike Goodchild, University of California-Santa Barbara

Biological Spatial Decision Support Systems

The following are recognized as biological SPDSS progenitors:

- R.L. Pressy, Australia, late 1980's: CODA, C-plan
- U.S. Forest Service (U.S. Department of Agriculture 1997)

Questions highlighted by research:

- Is any GIS a DSS? The answer seems to be no.
- Customers: their needs–knowledge engineering; the political dimension starts out mirroring a process, but may change the process.
- Science: underlying algorithm, appropriate model must be used for the task.

Major research in this area (1992-98):

- Institute of Electrical and Electronics Engineers
- American Computing Machines Society
- Operational research
- Business
- Models management system
- Management information science
- Allied fields

The DSS field has many assumed ancestors, such as microeconomic theory, cognitive psychology, applied psychology, behavioral decision theory, computer science, information theory, information economics, political and administrative sciences, human factors and ergonomics, management science, and others.

Overlapping research areas with DSS:

- Artificial intelligence
- Knowledge systems management
- Expert systems
- Human factors

DSS Issues:

- Perceptions of DSS: are they a solution in search of a problem?
- Oversell
- Requirement creep
- Bandwagon effects
- Costs
- User interface: who is the "user," and what is the output?
- The decision maker or a cadre of specialists?
- Decision-making culture of organization, cognitive styles, prior processes
- Inappropriate models challenged
- Legal issues
- Platforms
- Implementation acceptance by the customer

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Breakout Groups

Participants formed three breakout groups, a technical group, an outreach group, and a future group, to determine whether or not the DSS definition provided by the DSS Steering Committee meets BRD's requirements and to develop consensus on a DSS definition and a list of DSS components. The starting-point definition by the DSS Steering Committee follows:

A decision support system is "the combination of data, information, and computer- and noncomputer-based tools and services within a structured framework that can improve both the process and outcomes of decision making. Explicit recognition of the procedural component—that is, the decision-making process—is as important as the analytical component—databases, geographic information systems, and models."

Using this starting point definition, each breakout group was instructed to spend 30 min in review and to form various specialized definitions in order to arrive at a common definition. Afterward, all participants met in a plenary session for a brief discussion. Following the session, all groups were tasked with follow-on assignments.

Technical Group

Mike Frame, USGS CBI; Carl Korschgen, USGS UMESC, Facilitators

Management Level and General Public DSS Definition: A decision support system provides the right information in the right format at the right time to make resource management decisions.

Technical Audience DSS Definition: A decision support system provides stakeholders and decision makers with the right information in the right format at the right time. It is a structured framework that includes a combination of data, information, computer technology, and subject experts that can improve both the process and outcomes of natural resources decision making. It is recognized that needs and decision making processes of the stakeholders are essential components of a DSS. A DSS supports a defensible rationale for making decisions.

DSS Tools and Services: Geospatial technologies, descriptive and predictive models, visualization tools, other tools and services systems, stakeholder involvement mechanisms, databases and archives, Internet and the World Wide Web, logging and tracking tools, "error and uncertainty" tools, and "standard disclaimers."

DSS Decision Processes: Process mapping, goal setting, problem framing, intelligence gathering, evaluating and choosing alternatives, and learning from feedback.

Tasked with developing guidelines, policy, and standards related to data, hardware, and software interoperability, the technical group suggested the following recommendations:

- Conduct a more detailed survey of platforms, systems, and tools to determine if a set of standards is already being developed.
- Incorporate in guidelines that DSS software applications be developed as "program engines" to allow use with more than one dataset.
- Recommend that a more permanent tracking system be created to follow DSS projects, perhaps by adding a DSS question component to the BRD Science Information System. This component can query whether a DSS program, model, or system is under development.
- Investigate Cooperative Research and Development Agreement (CRADA) possibilities, perhaps through the Aurora Partnership.
- Maintain a web-based clearinghouse where information about current and proposed DSS projects can be reviewed (through NBII).
- Recommend that DSS developers consider delivering their products via the World Wide Web so that users have access when they need it.
- Recommend that regional office staff facilitate DSS project interaction among centers.
- Suggest scheduling semiannual DSS workshops.

Outreach Group

Maury Nyquist, USGS CBI, Facilitator

Management Level and General Public DSS Definition: A structured information delivery and data interpretation process to address specific management questions.

Technical Audience DSS Definition: The combination of data, information, and computer and noncomputer-based tools and services within a structured framework that can improve both the process and outcomes of decision making. Explicit recognition of the procedural component; that is, the decision-making process, is as important as the analytical component (databases, GIS, and models).

The ability to look at multiple scenarios is a fundamental component of the "system" part of a DSS. Existence of a feedback loop with adaptive management strategies is also an important aspect (i.e., it is an iterative process). The DSS must come up with the best information—not only science but other bases for decisions. Decision support systems combine and distill information from different fields: integration of these various types of information is the key.

A DSS must be in a usable format—it should not be designed to be run only by a specialist (must be "manager friendly"). To work well, its design must incorporate early input from the client so that it is not forced on the client after development.

Tasked with developing linkages with customers to implement decision support systems, to include relevance, customer requirements, education components, technology transfer, communications, and marketing, the outreach group suggested the following recommendations:

- As a science agency, we maintain a hierarchy of customers, including the DOI bureaus, other Federal agencies, state and local government, nongovernment organizations, and the public.
- We need to examine the question of minimum capabilities for a DSS: there is a problem with "throwing too many tools" into the DSS pot. A GIS may be a part of a DSS and may be the display tool for the resulting information, but alone a GIS is not a DSS.
- We need to develop linkages with customers to implement decision support systems. Include the following:
  - *True relevance* (make sure it meets an individual's needs on a one-on-one basis)
- Determine what kinds of decisions are being made on a routine basis and ask for ideas about how to support the decision-making process (rather than problems or needs).
- Different types of available decision support systems must be communicated to managers to help them understand the relevance of a given tool.
  - *Priorities*
    - Currently, more planning is needed.
    - Who should make the decisions about which decision processes receive DSS assistance?
    - Do we need a more structured Survey-wide process?
    - Is this just a matter of continuous and quality communication?
    - All part of an enterprise-wide effort in an interoperative manner? Competition with a demonstration of need from client (but no funds designated for this effort).
    - Competition may not be the best method; it may not produce the best science.
    - Where should funds be spent: agency-level projects such as Aurora Partnership or specific projects with very focused applications?
    - Should we try to broaden specific needs to a wider customer base?
  - *Customer requirements*
    - Cyclic and reevaluation of management needs.
    - Clients don't always know the right questions to ask nor what their needs really are.
    - Species versus ecosystem approaches.
    - Place-based versus function-based requirements.
    - Somewhere in the process we need to emphasize that data have differing qualities and accuracies ("not all data are equal"). This needs to be part of the science and the scientific dialog.
    - Need a "technical assistance" Bureau Information Need (BIN).
  - *Information sharing (education component)*
    - Share information about existing tools, capabilities, and possibilities (need a current web site presenting this information and frequently answered questions (FAQ's), including an easy walk-through concerning DSS definition, examples, and demonstrations).
    - Need to communicate the importance of making decisions based on scientific information rather than in an uninformed manner.
    - A DSS can be partly defined as how easy it is to use (simple, with limited functionality, to complex, with greater functionality). This may help someone understand that some decision support systems may be useful to them while others may not be useful.
  - *Technology transfer*
    - Be sure the agency is ready for the technology.
    - Provide good demonstrations.
    - The DSS user should not be dependent upon an operator to be able to utilize the system. Scientific expertise should always be part of the process.
  - *Communications (with managers and staff)*
    - Share information about existing tools, capabilities, and possibilities (need a current web site presenting this information and FAQ's).
    - There are many good DSS partnering efforts within BRD—how do we do more of this?
    - Develop more partnerships between centers.
  - *Marketing*
    - Identify strategic customers and key people.
    - Provide good demonstrations.
    - Create and provide brochures.
    - Provide formal presentations to Congressional staffers, headquarters staff, and others.
    - Provide personal and one-on-one communication.
    - Market to center director level.
    - Integrate with other USGS divisions.
    - Provide modularity around a generic decision-making process.
    - Should "sell" at the management level and at the ground level. Research should include interpretation (marketing). We may need to change the "rules" about research.

– *Training, support, and technical assistance*
  * Need to have technical assistance and support for only a designated time period.
  * Stakeholders are likely to modify the DSS tools that are developed. Must be sure that they do so accurately and correctly. "Lock" some parts and not others, depending upon potential for changes to inappropriately modify the DSS.
  * Provide unbiased structure/information at start to ensure proper function/design of DSS.

Future Group

James Getter, USGS CBI, Facilitator

DSS Definition: The combination of data, information, and computer and noncomputer-based tools and assistance within a structured framework that can improve both the process and outcomes of natural resources decision making. Explicit recognition of the human and procedural components "that is the customer's decision-making process" is as important as the analytical component (databases, geospatial technologies, and models).

- Research/science issues
  – Need user guidance for reviewing biological models—how good are they?
  – Need to relate local DSS to larger systems.
- Budget issues
  – Provide a minimal level of coverage (parks, Federal agencies): ArcView (ESRI, Redlands, California) to explore common look and feel; extensible over time; allows partnering with other bureaus and agencies.
  – Provide for interoperability, common data coverages.
  – Provide political viability and visibility.
  – How do we tie into biological sciences?
  – Revisit Fiscal Year (FY) 2000–01; add to Inventory and Monitoring DSS for U.S. Fish and Wildlife Service and National Park Service.
  – Create new DSS capabilities.
  – DOI support is required for any initiative.
  – Should be in something we are already doing (not in a new area).
  – Use existing data, recognizing common needs identified in BIN and other top DOI management needs. Tie to Habitat Conservation Plans, Comprehensive Conservation Plans, Federal Energy Regulatory Commission, Gateway to the Earth, information delivery systems. Don't tie to a single issue: work toward a common framework for all.
  – Explore proven marketing strategies.
  – Build on success stories: GAP, Adaptive Harvest Management of North American waterfowl. These programs worked because of strong partnerships and therefore are supported, and the partners are the owners of the systems.
  – Need to work from the bottom up.
  – There is a tradeoff between component interoperability and system-specific components. Interoperability is the goal, but system-specific modules are often necessary.
  – A general framework is transferable among systems. A small tool set is desirable. The framework should allow for integration of components from various places. It is the input/output between modules that must be standardized within the framework.
  – How do we move decision making from art (decision making based on intuition or feeling) + science to science + art. How do we get our partners to support this kind of system?
  – Concentrate on management problems where managers recognize that they need help.
  – Refuge managers generally recognize the problem. Regional managers generally recognize the problem. How do we get top-level and political support?
  – See Hood, L. 1998. Science-based stewardship: recommendations for implementing the National Wildlife Refuge System Improvement Act. Defenders of Wildlife, Washington, D.C.
- Attributes of a BRD DSS Budget Initiative
  – Must have partner support.
    * Need parallel complementary initiatives from USGS and DOI partners.
    * Must have buy-in and ownership by the ultimate manager and end-user.
    * Concentrate on management problems where the managers recognize the need.
  – Should link to current USGS/DOI initiatives such as FY 2000 support for DOI agencies, Gateway to the Earth, and USFWS Comprehensive Conservation Plans.
  – Investigate the use of CRADA's.
  – Ask for new money: ask for large new funds? Small-scale may be found in the current budget.
  – Tie the information components of current USGS initiatives into a unified DSS structure: develop a coordinated approach to deliver/provide scientific information to our clients in a format that can be used by clients and managers for decision making.

- Consider strategic versus tactical products: strategic are for long-term, large-scale framework and component development; tactical products are for small-scale, possibly site-specific projects that show success quickly. These can be used to justify the strategic efforts and can be used as test beds for developing new components that can be transferred to other decision support systems.
- BRD/USGS should become an Aurora partner.
- DSS products/components developed through this initiative should be interoperable so they can be reused in other decision support systems; however, there is a tradeoff between component interoperability and system-specific components. Interoperability is the goal, but system-specific modules are often necessary. A general framework is transferable among systems. The framework should allow for integration of components from various places—development of a DSS framework is therefore essential.
- A small tool set is desirable. Off-the-shelf tools should be used as much as possible, ideally with multiple vendors. Tool development may be in-house or in partnership with commercial developers. Commercial developers must, however, be controlled to ensure that final products are affordable by managers.

The future group was tasked to produce a research and science strategy agenda for BRD related to DSS that includes the following:

Budget issues (What are the cost considerations of conducting/developing DSS capabilities?).

- Development of funding initiatives (focus on DOI–USGS client resource management needs, including Government and Performance and Results Act (GPRA) and other budgeting opportunities).
- Consideration of standards from a strategic perspective (coordinating a BRD-wide and USGS-wide approach, actions to prevent duplication of effort, best practices, and other pertinent issues).

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DSS Steering Committee Meeting

Following workshop presentations, the DSS Steering Committee met on 29 October 1998 and developed a detailed outline for the DSS strategy document; provided a synopsis of where BRD is in the DSS arena and a summary of where BRD is heading, with suggestions regarding how to get there; and established specific time lines for the draft and final version of a formal report. Steering Committee members are listed below:

Frank D'Erchia–BRD Central Regional Office
Mike Frame–CBI
Tony Frank–BRD Eastern Regional Office
James Getter–CBI
Norman Hildrum–UMESC
Carl Korschgen–UMESC
Mike Mulligan –CBI
Maury Nyquist–CBI
Doug Ouren–MESC
Ralph Root–CBI
Greg Smith–BRD Science Staff
Peter Stine–WERC
Ken Williams– USGS Cooperative Research Units

Decision Support Systems Glossary

The glossary is used with permission from Power, D.J. 1999. Decision Support Systems Glossary. Decision Support Systems Resources. World Wide Web http://ddsresources.com/glossary.

Ad-Hoc Query - Any spontaneous or unplanned question or query. It is a query that consists of dynamically constructed SQL, which is usually constructed by desktop-resident query tools.

Ad-Hoc Query Tool - An end-user tool that accepts an English-like or point-and-click request for data and constructs an ad-hoc query to retrieve the desired data from a database.

Agents - Self-contained processes that run in the background on a client or server and that perform useful functions for a specific user/owner. Agents may monitor exceptions based on criteria or execute automated tasks. For example, once an event occurs a daemon performs a pre-defined action and then it returns to a monitoring state. See demon or daemon.

Aggregate or Aggregated Data - Data that result from applying a process to combine data elements. Data that are summarized.

Alerts - A notification from an event that a trigger has exceeded a predefined threshold. See agents.

Analytical Hierarchy Process - An approach to decision making that involves structuring multiple choice criteria into a hierarchy, assessing the relative importance of these criteria, comparing alternatives for each criterion, and determining an overall ranking of the alternatives.

Business Data - Data about people, places, things, business rules, and events used to operate a business. It is not metadata.

Business Intelligence - BI is a popularized, umbrella term introduced by Howard Dresner of the Gartner Group in 1989 to describe a set of concepts and methods to improve business decision making by using fact-based support systems. The term is sometimes used interchangeably with briefing books and executive information systems. A business intelligence system is a DSS.

Business Model - In a data warehouse it is the designer's view of how the business functions. The view can be from a process, data, event, or resource perspective and can be the past, present, or future state of the business.

Business Transaction - According to Microstrategy, it is a unit of work acted upon by a data capture system to create, modify, or delete business data. Each transaction represents a single valued fact describing a single business event.

Client/server architecture - A network architecture in which computers on a network act as a server managing files and network services OR as a client where users run applications and access servers. Clients rely on servers for resources like web pages, data, files, printing, and On-line Analytical Processing (OLAP).

Cognitive Overload - A psychological phenomenon characterized by an overload of information for a decision maker. The amount of information exceeds the person's cognitive capacity. DSS can reduce or increase cognitive overload.

Computer-mediated Communication - The use of computers to create, store, deliver, and process communications.

Computer Supported Cooperative Work - The use of computers to support cooperative work among multiple participants (e.g., collaborative authoring), as distinct from work that may not be cooperative.

Conferencing, Videoconferencing or Teleconferencing - Real-time, two-way communications. Audio-video telecommunication support of simultaneous interactions among participants (e.g., involving conference calls or videoconferencing).

Controllable Variables - Decision variables that can be changed and manipulated by a decision maker, such as quantity to produce, amount of resources to allocate, etc.

Corporate Planning System - A decision support system that holds and derives knowledge relevant to planning decisions that cut across organizational units and involve all of an organization's functions (i.e., its operations, finance, marketing, personnel, etc.).

Critical Success Factors - Key areas of business activity in which favorable results are necessary for a company to reach its goals.

Data - Binary (digital) representations of atomic facts, text, graphics, bit-mapped images, sound, analog or digital live-video segments. Data is the raw material of a system supplied by data producers and is used by information consumers to create information.

Data Conferencing - This term refers to a communication session in which two or more participants are sharing computer-based data in real-time. Any participants' keyboard/mouse can control screens of other participants. Voice communication can be out-of-band using a totally separate voice connection or in-band using a simultaneous voice and data technology.

Data Dictionary - A database about data and database structures. A catalog of all data elements, containing their names, structures, and information about their usage. A central location for metadata. Normally, data dictionaries are designed to store a limited set of available metadata, concentrating on the information relating to the data elements, databases, files and programs of implemented systems.

Data-driven DSS or Data-oriented DSS - This type of DSS emphasizes access to and manipulation of a time-series of internal company data and sometimes external data. Simple file systems accessed by query and retrieval tools provide the most elementary level of functionality. Data warehouse systems that allow the manipulation of data by computerized tools tailored to a specific task and setting or by more general tools and operators provide additional functionality. Data-driven DSS with OLAP or data mining tools provide the highest level of functionality and decision support that is linked to analysis of large collections of historical data. Early, very limited versions of data-driven DSS were called Retrieval-Only DSS by Bonczek et al. (1981).

Data Element - The most elementary unit of data that can be identified and described in a dictionary or repository which cannot be subdivided.

Data Mining - A class of analytical applications that search for hidden patterns in a data base. Data mining is the process of sifting through large amounts of data to produce data content relationships. This is also known as data surfing. Data mining tools use a variety of techniques including case-based reasoning, data visualization, fuzzy query and analysis, and neural networks. Case-based reasoning tools provide a means to find records similar to a specified record or records. These tools let the user specify the "similarity" of retrieved records. Data visualization tools let the user easily and quickly view graphical displays of information from different perspectives.

Data Quality - High quality data is accurate, timely, meaningful, and complete. DSS must have high quality data; low quality data can result in bad decisions. Assessing or measuring data quality is a preliminary task associated with evaluating the feasibility of a data-driven DSS project.

Data Warehouse - A database designed to support decision making in organizations. It is batch updated and structured for rapid online queries and managerial summaries. Data warehouses contain large amounts of data. A data warehouse is a subject-oriented, integrated, time-variant,nonvolatile collection of data in support of management's decision making process. Check "What is a Data Warehouse" by W.H. Inmon at http:// www.cait.wustl.edu/cait/papers/prism/ vol1_no1/. According to Kimball (1996) "A data warehouse is a copy of transaction data specifically structured for query and analysis" (see "A Definition of Data Warehousing" by I. Greenfield at http:// pwp.starnetinc.com/larryg/defined.html.)

Data Visualization - This term refers to presenting data and summary information using graphics, animation, 3-D displays, and other multimedia DSS tools.

Decision - The choice of one from among a number of alternatives; a statement indicating a commitment to a specific course of action.

Decision Analysis Tools - DA tools help decision makers decompose and structure problems. The aim of these tools is to help a user apply models like decision trees, multi-attribute utility models, bayesian models, Analytical Hierarchy Process (AHP), etc. Examples of DA software packages include AliahThink, BestChoice3, Criterium Decision Plus, DecideRight, DecisionMaker, Demos, DPL, Expert Choice, Strad, Supertree, and Which and Why.

Decision Room - A physical arrangement for a group DSS in which workstations are available to participants. The objective for using a Decision Room is to enhance and improve the group's decision-making process.

Decision Systems are computer based programs and technologies intended to make routine decisions, monitor and control processes, and aid or assist decision makers in semi-structured and/or non-routine decision situations.

Decision Support Systems (DSS) are interactive computer-based systems intended to help decision makers utilize data and models to identify and solve problems and make decisions. The "system must aid a decision maker in solving unprogrammed, unstructured (or "semistructured") problems...the system must possess an interactive query facility, with a query language that ...is ...easy to learn and use" (Bonczek et al. 1981:19). DSS help managers/ decision makers use and manipulate data; apply checklists and heuristics; and build and use mathematical models. According to Turban (1999), a DSS has four major characteristics: DSS incorporate both data and models; they are designed to assist managers in their decision processes in semistructured (or unstructured) tasks; they support, rather than replace, managerial judgment; and their objective is to improve the effectiveness of the decisions, not the efficiency with which decisions are being made.

Decision Variables - In a model-driven DSS a decision variable is a changing factor in the model that is determined by a decision maker. They are sometimes called independent variables, and the range of values for the decision variables constrain the choices of the decision maker.

Demon or Daemon - A computer program or procedure that is automatically activated when it recognizes a specific, predefined state or condition.

Descriptive Model - Physical, conceptual, or mathematical models that describe situations as they are or as they actually appear.

Deterministic Model - Mathematical models that are constructed for a condition of assumed certainty. The models assume there is only one possible result (which is known) for each alternative course or action.

Development Environment - The DE is used by a designer/builder. A development environment typically includes software for creating and maintaining a knowledge base and software for the inference engine.

Dialog Generation and Management System (DGMS) - A software management package in a DSS whose functions in the dialog subsystem is similar to that of a DBMS in a database (see Sprague and Carlson 1982).

Dialog System - The hardware and software that create and implement a user interface for a DSS. A DSS dialog system creates the human-computer interface.

Domain Expert - A person who has expertise in the domain in which a specific expert system is being developed. A domain expert works closely with a developer (known as a knowledge engineer) to capture the expert's knowledge (especially rule and relationship information) in a computer readable representation often called a knowledge base.

Drill Down/Up - An analytical technique that lets a DSS user navigate among levels of data ranging from the most summarized (up) to the most detailed (down).

DSS Generator - Computer software package that provides tools and capabilities that help a developer quickly and easily build a specific Decision Support System (see Sprague and Carlson 1982:11). Excel is an example of a DSS Generator. Many companies market tools for building DSS and EIS.

DSS Development Tools - Software components (such as editors, code libraries, specific objects, visual interfaces) that facilitate the development of a specific DSS.

e-Meetings - A term for a meeting supported by full-motion video, audio, and web meeting tools. One or more participants in the meeting is participating remotely in the meeting. It is possible that all participants are in different physical locations.

Enterprise-wide DSS - A DSS that supports a large group of managers in a networked client-server environment with a specialized data warehouse as part of the DSS architecture.

Evolutionary (Iterative) Design Process - A systematic process for system development that is recommended for use in creating DSS. A portion of the DSS system is quickly constructed, then tested, improved, and enlarged in systematic steps. This methodology is similar to prototyping.

Exception Reporting - A reporting philosophy and approach that supports Management by Exception. Reports should be designed to display significant exceptions in results and data. The idea is to "flag" important information and bring it quickly to the attention of managerial users of the report. Exception reporting can be implemented in any type of DSS, but it is particularly useful in data-driven DSS and EIS.

Executive Information Systems (EIS) - A computerized system intended to provide current and appropriate information to support executive decision making for managers using a networked workstation. The emphasis is on graphical displays and an easy to use interface that present information from the corporate database. They are tools to provide canned reports or briefing books to top-level executives. They offer strong reporting and drill-down capabilities.

Executive Support Systems (ESS) - An executive information system (EIS) that includes specific decision aiding and/or analysis capabilities.

Expert Systems - are man-machine systems with specialized problem-solving expertise. The "expertise" consists of knowledge about a particular domain, understanding of problems within that domain, and "skill" at solving some of these problems.

Facilitator - A person(s) who manages the use of a group decision support system from initial planning through actual operation.

Feasibility Study - A study of the technical and economic prospects for developing a system prior to actually committing resources to actually developing it.

Functional DSS - A decision support system that holds and derives knowledge relevant for decisions about some function an organization performs (e.g., a marketing function, a production function).

Generators - Software packages that are designed to expedite programming efforts that are required to build information systems, especially expert and decision support systems.

Goal-seeking - The capability of asking the computer software what values certain variables must have in order to attain desired goals. It is a tool that uses iterative calculations to find the value required in one cell (variable) in order to achieve a desired value in another cell. A common use of the goal-seeking feature in a spreadsheet is calculating a break-even quantity.

Geographic Information Systems (GIS) - A support system that represents data using maps. It helps people access, display and analyze data that have geographic content and meaning. Check U.S. Geological Survey page on geographic information systems at http://www.usgs.gov/research/gis/title.html. Examples of software packages include ArcView, Map/IDIS, Proximity, and TargetView.

Graphical User Interface (GUI) - A program interface that uses a computer's graphics capabilities to make the program easier to use. Graphical interfaces use a pointing device to select objects, including icons, menus, text boxes, etc. A GUI includes standard formats for representing text and graphics.

Group Decision Support Systems (GDSS) - An interactive, computer-based system that facilitates solution of unstructured problems by a set of decision makers working together as a group. It aids groups, especially groups of managers, in analyzing problem situations and in performing group decision-making tasks.

Groupware - Is software designed to support more than one person working on a shared task. Groupware is an evolving concept that is more than multiuser software which allows access to the same data. Groupware provides a mechanism that helps users coordinate and keep track of on-going projects. It allows people to work together through computer-supported communication, collaboration, and coordination. Lotus Notes, Microsoft Exchange, Communicator, Novell GroupWise, Netscape SuiteSpot, Eclipse, Team Talk, and Internet Explorer/NetMeeting are examples of groupware products.

Heuristics - The informal, judgmental knowledge of an application area that constitutes the "rules of good judgment" in the field. Heuristics also encompass the knowledge of how to solve problems efficiently and effectively, how to plan steps in solving a complex problem, how to improve performance, and so forth. From the Greek word "Heuriskein" meaning "to discover."

Hypermedia - Combination of several types of media such as text, graphics, audio, and video.

Hypertext - An approach for handling text and other information that allows users to jump from a given topic, whenever he or she wishes, to related topics. A knowledge management technique in which knowledge is represented in linked documents and processed in a way that allows a user to select a highlighted marker on the currently viewed page and access a linked page about a topic indicated by the marker.

Icon - A visual, graphic representation of an object, word, or concept.

Independent Variables - Variables in a model that are controlled by the environment and that influence the results of a decision (also called Input Variables, parameters, givens).

Inference - The process of drawing a conclusion from given evidence. To reach a decision by reasoning.

Inference Engine - That part of an expert system that actually performs the reasoning function.

Information - Data that has been processed to add or create meaning and hopefully knowledge for the person who receives it. Information is the output of information systems.

Information Economics - This term refers to an approach to evaluating DSS/IS projects using a scoring approach to cost/benefit analysis that assesses technical and company tangible and intangible benefits and costs (see Parker et al. 1989).

Information Systems Architecture - A formal definition of the business processes and rules, systems structure, technical framework, and product technologies for business information systems. An information systems architecture consists of four layers: business process architecture, systems architecture, technical architecture, and product delivery architecture.

Interdependent Decisions - A series of decisions that are interrelated. A sequential set of decisions are usually interdependent.

Internet - The Internet (capitalized) refers specifically to the DARPA Internet and the TCP/IP protocols it uses. The Internet is a collection of packet-switching networks and routers that uses the TCP/IP protocol suit and functions as a single, cooperative virtual network. It is a global web connecting more than one million computers. See http://www.stars.com/Internet/About.html for more information about the Internet.

Intranet - An internal organizational network using TCP/IP with at least one web server that is only accessible by an organization's members or others who have specific authorization. A firewall and password protection limit access to the network. The intranet is used to share corporate information, including DSS capabilities. See web-based DSS at http://dss.cba.uni.edu/dss/online.html and check the Intranet FAQ at http://www.intrack.com/intranet/ifaq.shtml.

Knowledge - Knowledge refers to what one knows and understands. Knowledge is sometimes categorized as either unstructured, structured, explicit or tacit. What we know we know is explicit knowledge. Knowledge that is unstructured and understood, but not clearly expressed is implicit knowledge. If the knowledge is organized and easy to share then it is called structured knowledge. To convert implicit knowledge into explicit knowledge, it must be extracted and formatted.

Knowledge Acquisition - The extraction and formulation of knowledge derived from various sources, especially from experts.

Knowledge Base - A collection of facts, rules, and procedures organized into schemas. The assembly of all the information and knowledge of a specific field of interest.

Knowledge Engineer - An AI specialist responsible for the technical side of developing an expert system. The knowledge engineer works closely with the domain expert to capture the expert's knowledge in a knowledge base.

Knowledge Engineering (KE) - The engineering discipline that involves integrating knowledge into computer systems in order to solve complex problems normally requiring a high level of human expertise.

Knowledge Management (KM) - KM is the distribution, access, and retrieval of unstructured information about "human experiences" between interdependent individuals or among members of a workgroup. Knowledge management involves identifying a group of people who have a need to share knowledge, developing technological support that enables knowledge sharing, and creating a process for transferring and disseminating knowledge.

Knowledge Management Software (KMS) - Software that can store and manage unstructured information in a variety of electronic formats. The software may assist in knowledge capture, categorization, deployment, inquiry, discovery, or communication. Products include electronic document management systems (EDMS). Visit KMWorld at http://www.kmworld.com/.

Linear Programming - A mathematical model for optimal solution of resource allocation problems.

Metadata or Meta Data - Data about the data in a data warehouse. Metadata provides a directory to help the DSS locate the contents of the data warehouse; it is a guide to mapping data as it is transformed from the operational environment to the data warehouse environment; and it serves as a guide to the algorithms used for summarization of current detailed data. Metadata is semantic information associated with a given variable. Metadata must include business definitions of the data and clear, accurate descriptions of data types, potential values, original source system, data formats, and other characteristics. Metadata defines and describes business data. Examples of metadata include data element descriptions, data type descriptions, attribute/property descriptions, range/domain descriptions, and process/method descriptions. The repository environment encompasses all corporate metadata resources: database catalogs, data dictionaries, and navigation services. Metadata includes things like the name, length, valid values, and description of a data element. Metadata is stored in a data dictionary and repository. It insulates the data warehouse from changes in the schema of operational systems.

Methodology - A system of principles, practices, and procedures applied to a specific branch of knowledge.

Middleware - A communications layer that allows applications to interact across hardware and network environments.

Model Base - A collection of preprogrammed quantitative models (e.g., statistical, financial, optimization) organized as a single unit.

Model-driven DSS or Model-oriented DSS - This type of DSS emphasizes access to and manipulation of a model, e.g., statistical, financial, optimization and/or simulation. Simple statistical and analytical tools provide the most elementary level of functionality. Some OLAP systems that allow complex analysis of data may be classified as hybrid DSS systems providing both modeling and data retrieval and data summarization functionality. Data mining is also a hybrid approach to DSS. In general, model-driven DSS use complex financial, simulation, optimization and/or rule (expert) models to provide decision support. Model-driven DSS use data and parameters provided by decision makers to aid decision makers in analyzing a situation, but they are not usually data intensive, that is very large data bases are usually not needed for model-driven DSS. Early versions of model-driven DSS were called Computationally Oriented DSS by Bonczek et al. (1981).

Modeling Tools - Software programs that help developers and users build mathematical models quickly. Spreadsheets and planning languages like IFPS are modeling tools.

Multidimensional Database (MDBS and MDBMS) - A database that lets users analyze large amounts of data. An MDBS captures and presents data as arrays that can be arranged in multiple dimensions. Variables are the objects that hold data in a multidimensional database. These are simply arrays of values (usually numeric) that are "dimensioned" by the dimensions in a database. For example, a UNITS variable may be dimensioned by MONTH, PRODUCT, and REGION. This three-dimensional variable or array is often visualized as a cube of data. Multidimensional databases can have multiple variables, with common or a unique set of dimensions. This multidimensional view of data is especially powerful for OLAP applications.

Multiparticipant DSS - A decision support system that supports multiple participants engaged in a decision-making task (or functions as one of the participants). See group DSS.

Multipoint Conference - An audio, data and/or video conference among more than two remote participants.

Multipoint Control Unit (MCU) - A device used to link remote sites into a single conference call or a device to manage several simultaneous, independent conferences.

Normalization - The process of reducing a complex data structure into its simplest, most stable structure. In general, the process entails the removal of redundant attributes, keys, and relationships from a conceptual data model.

Object - A person, place, thing, or concept that has characteristics of interest to an environment. In terms of an object-oriented system, an object is an entity that combines descriptions of data and behavior.

On-line Analytical Processing (OLAP) - Software for manipulating multidimensional data from a variety of sources that has been stored in a data warehouse. The software can create various views and representations of the data. OLAP software provides fast, consistent, interactive access to shared, multidimensional data. Check the Guide to OLAP Terminology from the OLAP Council at http://dss.cba.uni.edu/glossary/olaptrms.html.

Operational or Transaction Database - The database-of-record for a transaction-update system. The operational database is the source of data for the data warehouse. It contains detailed data used to run the day-to-day operations of the business. The data continually changes as updates are made and reflect the current value of the last transaction.

Optimize - The decision strategy of choosing the alternative that gives the best or optimal overall value.

Organizational DSS - A multiparticipant DSS designed to support a decision maker in a setting that has a more elaborate infrastructure than a group (i.e., involving specialized roles, restricted communication patterns, differing authority levels). See enterprise-wide DSS.

Pivot - Changing the dimensional orientation of a display or report. See rotate in the OLAP Guide to terms at http://dss.cba.uni.edu/glossary/olaptrms.html.

Planning - A managerial function concerned with making forecasts, formulating outlines of things to do, and identifying methods to accomplish them.

Prototyping - A strategy in system development in which a scaled down system or portion of a system is constructed in a short time, tested, and improved in several iterations. A prototype is an initial version of a system that is quickly developed to test the effectiveness of the overall design being used to solve a particular problem. Prototyping is similar to the Evolutionary (Iterative) Design Process. It is sometimes termed rapid prototyping and is similar to rapid application development (RAD).

Query - Generically, query means question. Usually it refers to a complex SQL SELECT statement for decision support. See Ad-Hoc Query.

Rapid Application Development (RAD) - Part of a methodology that specifies incremental development with constant feedback from the customers. The point is to keep projects focused on delivering value and to keep clear and open lines of communication. Oral and written communication is not completely adequate for specification of computer systems. RAD overcomes the limitations of language by minimizing the time between concept and implementation.

Rational Decision Behavior -Behavior that is goal-oriented in reaching a decision. Behavior is guided by the consequences likely to result from the selection of a given alternative. A decision maker believes based upon analysis that a chosen alternative will result in achieving one or more desired objectives. Rational decision behavior should be supported by DSS.

Record - A group of data values consisting of one value for each of a prescribed set of relational fields; an occurrence of a record type.

Report and Query tools - these tools produce a tabular list of information from data stored in a relational database. Examples include Microsoft Access and Brio Query.

Representation - The formulation or view of a problem. Developed so the problem will be easier to solve.

Result Variables - In a model-driven DSS a result variable shows the consequences of changing decision variables. Result variable are also referred to as dependent variables.

ROMC (Representation, Operations, Memory Aids, Mechanism Control) Design Approach - A systematic approach for developing large-scale DSS, especially user interfaces. It is user-oriented approach for stating system performance requirements (see Sprague and Carlson 1982).

Rule - A formal way of specifying a recommendation, directive, or strategy, expressed as an IF premise THEN conclusion.

Scalability - The ability to scale hardware and software to support larger or smaller volumes of data and more or less users. The ability to increase or decrease size or capability in cost-effective increments with minimal impact on the unit cost of business and the procurement of additional services.

Semistructured Decisions - Decisions in which some aspect of the problem are structured and others are unstructured.

Sensitivity Analysis - Running a decision model several times with different inputs so a modeler can analyze the alternative results.

Shell - An expert system development tool consisting of two stand-alone pieces of software: a rule set manager and an inference engine capable of reasoning with rules set built with the rule set manager. A shell is a complete expert system stripped of its specific knowledge.

Simulation - A technique for conducting one or more experiments that test various outcomes resulting from a quantitative model of a system.

Specific DSS - A computer-based system that actually helps a person accomplish a specific task. "Specific DSS are the hardware/software that allow a specific decision maker or group of them to deal with specific sets of related problems" (see Sprague and Carlson 1982:10).

Spreadsheet - In the accounting world a spreadsheet was and is a large sheet of paper that lays everything out for a businessperson. It spreads or shows all of the costs, income, taxes, etc., on a single sheet of paper for a manager to look at when making a decision. An electronic spreadsheet organizes information into columns and rows. The data can then be "added up" by a formula to give a total or sum. The spreadsheet summarizes information from many sources in one place and presents the information in a format to help a decision maker see the financial "big picture" for the company. A program that has a collection of cells whose values can be displayed on a computer screen. By changing cell definitions and having all cell values reevaluated, a user can readily observe the effects of those changes. Decision support systems built using spreadsheet software are sometimes called Spreadsheet DSS. See "A Brief History of Spreadsheets" by Daniel Power at http://dss.cba.uni.edu/dss/sshistory.html.

Star Schema - A relational database schema organized around a central table (fact table) joined to a few smaller tables (dimension tables) using foreign key references. The fact table contains raw numeric items that represent relevant business facts (price, discount values, number of units sold, dollar value, etc.). The facts are typically additive and are accessed via dimensions. Since the fact tables are presummarized and aggregated along business dimensions, these tables tend to be very large. The basic premise of star schemas is that information can be classified into two groups: facts and dimensions. Facts are the core data element being analyzed. For example, units of individual items sold are facts, while dimensions are attributes about the facts. Dimensions are the product types purchased and the date of purchase. The star schema has also been called a star-join schema, data cube, data list, grid file, and multidimensional schema. The name star schema comes from the pattern formed by the entities and relationships when they are represented as an entity-relationship diagram (ERD). The results of a business activity are at the center of the star surrounded by the people, places, and things that come together to perform this activity. These dimensions are the points of the star.

Strategic Planning - A decision-making process in which decisions are made about establishing organizational purposes/missions, determining objectives, selecting strategies, and setting policies.

Structured Decisions - Standard or repetitive decision situations for which solution techniques are already available (also sometimes called routine or programmed decisions). The structural elements in the situation (e.g., alternatives, criteria, environmental conditions) are known, defined and understood.

Symbolic Processing - Use of symbols, rather than numbers, combined with rules-of-thumb (or heuristics), in order to process information and solve problems.

Systems Development Life Cycle (SDLC) - A process by which systems analysts, software engineers, programmers, and end-users build systems. It is a project management tool, used to plan, execute, and control systems development projects. The steps in the cycle include: (1) determine user requirements; (2) systems analysis; (3) overall system design; (4) detailed system design; (5) programming; (6) testing; and (7) implementation. Each step is concluded by developing a written document that must be reviewed and approved before the next step begins.

Ticker - A small Java Applet that displays a specific set of headlines, information, etc. Every web page that wants to display a Ticker must add some special HTML code into the page. This code ensures that the JAVA Applet is loaded from a server. Some parameters control the visible output like coloring and of course they control which news is loaded. Visit http://7am.com/ticker/ or http://www.tickerland.com/.

Unstructured Decisions - This type of decision situation is complex, and no standard solutions exist for resolving the situation. Some or all of the structural elements of the decision situation are undefined, ill-defined, or unknown. For example, goals may be poorly defined, alternatives may be incomplete or noncomparable, and choice criteria may be hard to measure or difficult to link to goals.

User-friendly - An evaluative term for a decision support system's user interface. The phrase indicates that users judge the user interface as how easy to learn, understand, and use it is.

User Interface (or "Human–Computer Interface") - The component of a computerized support system that allows bidirectional communication between the system and its user. This is also called the dialogue component of a DSS. An interface is a set of commands or menus through which a user communicates with a program.

Web-based DSS - A computerized system that delivers decision support information or decision support tools to a manager or business analyst using a "thin-client" web browser like Netscape Navigator or Internet Explorer. The computer server that is hosting the DSS application is linked to the user's computer by a network with the TCP/IP protocol. In many companies, a web-based DSS is synonymous with an enterprise-wide DSS that is supporting large groups of managers in a networked client-server environment with a specialized data warehouse as part of the DSS architecture.

"What If" Analysis - The capability of "asking" the software package what the effect will be of changing some of the input data or independent variables.

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Appendix A

http://bp.cr.usgs.gov/dsssig/

U.S. Geological Survey Decision Support Systems Special Interest Group (DSSSIG) DSSSIG Questionnaire Page

Definition: A decision support system (DSS) is defined as "the combination of data, information, and computer and non-computer based tools and services within a structured framework, that can improve both the process and outcomes of decision making. Explicit recognition of the procedural component—that is the decision making process—is as important as the analytical component—databases, geographic information systems, and models."

Name: (required)

First: **Last:**

Title:

Telephone number:

Email address: (required)

Location: (required)

Alabama Cooperative Fish and Wildlife Research Unit
Alaska Cooperative Fish and Wildlife Research Unit
Alaska Biological Science Center
Arizona Cooperative Fish and Wildlife Research Unit
Arkansas Cooperative Fish and Wildlife Research Unit
Biological Resources Division Headquarters
California Cooperative Fishery Research Unit

If your **location** is **<u>not</u>** within the above list, then please enter it here:

City: **State:** AL AK AS

USGS Organization:

Biological Resources Division
Geology Division
National Mapping Division

Are you interested in **subscribing** to the DSSSIG via email? ○ **Yes** ◉ **No**

DSS use status:

Researcher that **uses** or has need of **DSS technologies** ☐

Technologist that **develops DSS modules** ☐

Other

Do you think the definition of DSS needs to be **amended**? ○ Yes ◉ No

How?

For what **purpose** do you have a need for **DSS technologies**?

Are you **currently using** DSS technologies? ○ **Yes** ◉ **No**

Where do you **utilize** the DSS technologies?

How do you **utilize** the DSS technologies?

Have you **developed** a DSS? If so, provide information concerning it (ie, purpose, hardware/software, geospatial based or not, is it downloadable, where)?

Would you be interested in participating in a **DSS workshop on October 27-29th (BRD Staff Only)**?

○ **Yes** ◉ **No**

Do you have a **DSS Website?** ○ **Yes** ◉ **No**
If yes, what is its **URL**:

What **DSS sites**, if any, do you use? List **URLS**:

Do you have any **Knowledge Systems, Expert Systems, Artificial Intelligence (AI), etc.** that you use? ○ Yes ◉ No

If yes, what **system** is it?

Would you like **your site linked** off of a DSSSIG Web Page? ○ **Yes** ◉ **No**
If yes, provide the **URL** that you want to have linked:

SUBMIT Click here to **submit all** of the **DSSSIG information** that you have entered above.

RESET Click here to **clear all** of the **DSSSIG information** that you have entered on this page.

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http://bp.cr.usgs.gov/dsssig/dsssigbrd.cfm

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Survey Results

The USGS Decision Support System (DSS) Questionnaire results indicated that 57 individuals were using decision support systems or had need for this technology in their organizations: Biological Resources Division, 29; Geologic Division, 13; Water Resources Division, 9; National Mapping Division, 5; no organization given, 1.

A nonexhaustive list of some usage areas reported by those who are actively using, developing, and contemplating using DSS includes:

- Helping with Gap Analysis Program data.
- Estimating environmental properties.
- Developing a long-term ecological monitoring program for the National Park Service.
- Providing interpreted information to natural resources staff at the National Park Service and the U.S. Fish and Wildlife Service.
- Understanding the Upper Missouri River Basin.
- Conducting brown bear habitat studies.
- Integrating models of temporal and spatial data.
- Conducting river-related inventories.
- Determining quality assurance of real-time stream flow data.
- Predicting drought.
- Managing salmonid populations.
- Managing contaminated sediment.
- Predicting location of packrat middens.
- Natural attenuation of solvent-contaminated groundwater.
- Examining ecotoxological data.
- Restoring wetlands.

Thirteen respondents indicated that they used or were familiar with expert systems, knowledge-based systems, or artificial intelligence: Biological Resources Division, 9; Geologic Division, 2, Water Resources Division, 1. Systems mentioned by respondents:

- EMDS Netweaver
- Ecosystem Management System (U.S. Fish and Wildlife Service)
- PredicTox
- Wetland Value Assessment Decision Support System
- WINEXP
- Expert Choice
- VegSpec 2.0
- Bighorn HEP
- Resolver/Netrunner
- IDRISI Geographic Information System

Appendix B

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REPORT DOCUMENTATION PAGE			Form approved OMB No. 0704-0188

1. AGENCY USE ONLY (Leave Blank)	**2. REPORT DATE** December 1999	**3. REPORT TYPE AND DATES COVERED** Information and Technology Report

4. TITLE AND SUBTITLE Proceedings of the Workshop "Development of Biological Decision Support Systems for Resource Managers" Denver, Colorado, October 27-29, 1998	**5. FUNDING NUMBERS**
6. AUTHOR(S) Getter, J., T. D'Erchia, and R. Root	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESSES U.S. Department of the Interior U.S. Geological Survey Biological Resources Division	**8. PERFORMING ORGANIZATION REPORT NUMBER** USGS/BRD/ITR--2000-0002
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESSES U.S. Department of the Interior U.S. Geological Survey	**10. SPONSORING, MONITORING AGENCY REPORT NUMBER**
11. SUPPLEMENTARY NOTES	
12a. DISTRIBUTION/AVAILABILITY STATEMENT Release unlimited. Available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161 (1-800-553-6847 or 703-487-4650). Available to registered users from the Defense Technical Information Center, Attn: Help Desk, 8725 Kingman Road, Suite 0944, Fort Belvoir, VA 22060-6218 (1-800-225-3842 or 703-767-9050).	**12b. DISTRIBUTION CODE**

13. ABSTRACT (Maximum 200 words)

The format for this 3-day workshop (27–29 October 1998) included plenary presentations by USGS Biological Resources Division (BRD) and U.S. Fish and Wildlife Service personnel who use and develop decision support systems (DSS); breakout sessions addressing DSS technical information aspects, outreach/customer requirements, and future perspectives; and a DSS Steering Committee meeting to evaluate workshop goals and to provide guidance for future efforts. Steering committee action items developed from workshop inputs were to (1) develop a "DSS framework" document for use in biological research, (2) develop a "proof of concept" DSS based upon the framework document, and (3) integrate decision support systems into BRD program elements.

14. SUBJECT TERMS (Keywords) Biological Resources Division, decision support systems, DSS, GIS, USGS	**15. NUMBER OF PAGES** v + 41
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	**18. SECURITY CLASSIFICATION OF THIS PAGE**	**19. SECURITY CLASSIFICATION OF ABSTRACT**	**20. LIMITATION OF ABSTRACT**
Unclassified	Unclassified	Unclassified	Unlimited

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Technical Editor Tammy Charron, Johnson Controls World Services

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