



United States  
Department of  
Agriculture

Forest Service

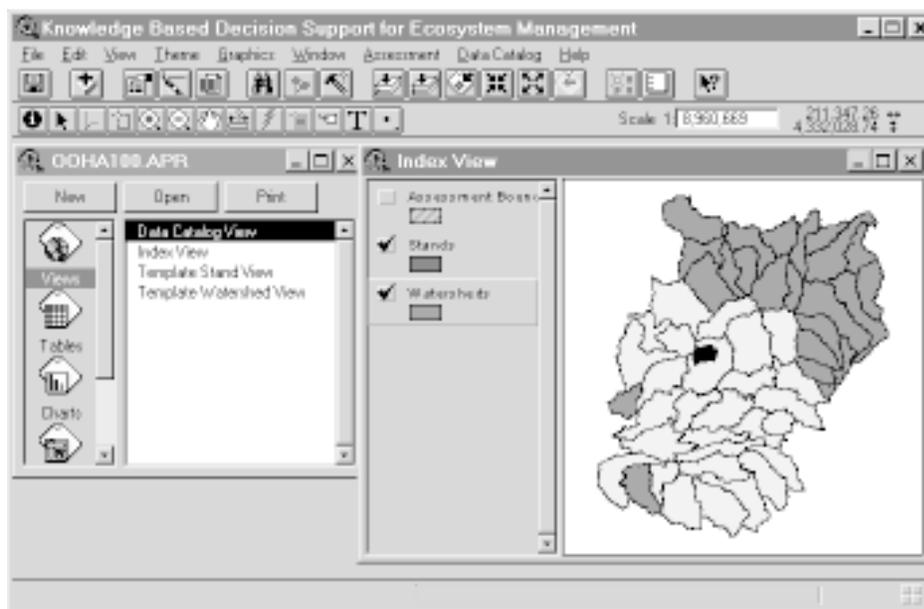
Pacific Northwest  
Research Station

General Technical  
Report  
PNW-GTR-470  
October 1999



# EMDS Users Guide (Version 2.0): Knowledge- Based Decision Support for Ecological Assessment

Keith M. Reynolds





## **Author**

KEITH M. REYNOLDS is a research forester, Forestry Sciences Laboratory, 3200 SW Jefferson Way, Corvallis, OR 97331.

*ArcView GIS software GUI screen capture courtesy of ESRI and used herein with permission. ArcView GIS logo is a trademark of ESRI.*



## Abstract

**Reynolds, Keith M. 1999.** EMDS users guide (version 2.0): knowledge-based decision support for ecological assessment. Gen. Tech. Rep. PNW-GTR-470. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 63 p.

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

**Keywords:** Ecosystem management, ecological assessment, knowledge base, decision support, geographic information system, ecosystem analysis, ecosystem states, ecosystem processes.



## Contents

- v **System Requirements**
- v **Text Formatting Conventions**
- v **System Installation and Initial Setup**
- v Installing EMDS
- vi Running EMDS Sample Projects
- 1 **Introduction**
- 2 A Brief History
- 2 EMDS Features
- 3 Overview of EMDS System Components
- 5 Key Concepts
- 5 Landscape Feature
- 5 Influence of Missing Data
- 5 Knowledge Base
- 6 Knowledge-Based Reasoning
- 7 Inference Engine
- 7 Fuzzy Logic
- 9 **EMDS Online Help**
- 10 ArcView System
- 10 ArcView Features
- 10 ArcView and EMDS Projects
- 11 Multiple EMDS Projects
- 11 Multiple EMDS Assessments Within an EMDS Project
- 12 Multiple Analyses Within an EMDS Assessment
- 12 EMDS Data Engine
- 13 Views
- 13 Index View
- 13 Template View
- 14 Assessment View
- 15 Setting Up an EMDS Project
- 15 Creating a Base ArcView Project
- 18 Creating a new EMDS Project

|    |   |
|----|---|
| 18 | Completing Setup of a New EMDS Project            |
| 19 | Neighborhood Attribute Tool                       |
| 20 | Using EMDS with GRID and Spatial Analyst          |
| 20 | Managing EMDS Projects                            |
| 20 | ArcView Assessment Menu                           |
| 22 | <b>Netweaver System</b>                           |
| 22 | Relation of Analysis Topics to NetWeaver Networks |
| 22 | NetWeaver Engine                                  |
| 24 | NetWeaver Knowledge Bases                         |
| 24 | Dependency Networks                               |
| 25 | Data Links  |
| 25 | Truth Values                                      |
| 26 | Knowledge Base Processing                         |
| 28 | <b>Assessment System</b>                          |
| 28 | Assessment Management                             |
| 29 | Creating a New Assessment                         |
| 29 | Opening an Existing Assessment                    |
| 30 | Saving an Assessment                              |
| 30 | Assessment System Components                      |
| 30 | Instantiated Knowledge Bases                      |
| 30 | Assessment Interface                              |
| 31 | Assessment Button Bar                             |
| 33 | Assessment Menu Bar                               |
| 36 | Assessment Windows                                |
| 41 | Accessory Button Set                              |
| 41 | Setting Values for Topics and Data                |
| 42 | Performing an Analysis                            |
| 48 | Hotlink Browser                                   |
| 48 | Opening the Hotlink Browser                       |
| 49 | Hotlink Browser Outline Window                    |
| 50 | Hotlink Browser Network Window                    |
| 50 | Hotlink Browser Buttons                           |



|    |                                    |
|----|------------------------------------|
| 51 | Data Acquisition Manager           |
| 51 | DAM Process                        |
| 54 | DAM Results                        |
| 56 | Scenarios                          |
| 56 | Creating a New Scenario            |
| 56 | Setting Values for Topics and Data |
| 57 | Saving an Existing Scenario        |
| 57 | Saving a Scenario Under a New Name |
| 58 | Deleting a Scenario                |
| 58 | Running a Scenario                 |
| 58 | Returning to Normal Analysis Mode  |
| 59 | <b>Acknowledgments</b>             |
| 60 | <b>Literature Citations</b>        |

## System Requirements<sup>1</sup>

| Component         | Required                       | Recommended                  |
|-------------------|--------------------------------|------------------------------|
| Input device      | Mouse                          |                              |
| Applications      | ArcView 3.0a<br>NetWeaver 1.1g |                              |
| Operating system  | Windows 95                     | Windows 95 or Windows NT 4.0 |
| Processor         | Pentium CPU                    |                              |
| RAM               | 32 MB                          | 64 MB                        |
| Screen resolution | 640 by 480 pixels              | 800 by 600 pixels or better  |
| Color resolution  | 256 colors                     | 256 colors or better         |

## Text Formatting Conventions

The following conventions are used for text formatting in EMDS help:

PLAIN UPPERCASE TEXT indicates a folder (directory) or file name.

*Italic text* indicates a graphic object such as a button, menu choice, etc.

**Plain bold** text is used for emphasis.

## System Installation and Initial Setup

### Installing EMDS

To install EMDS:

1. Load the EMDS distribution CD in the CD drive.
2. Open Windows Explorer in Windows 95 (or File Manager in Windows 3.1).
3. Select the *CD icon* to display the folders (directories) on the drive.
4. In the tree view (left pane), click on the *root icon* to highlight it, if necessary.
5. In the contents pane, double click on SETUP.EXE to run the EMDS setup application.

---

<sup>1</sup> The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

6. When the setup application starts, it first asks for the drive and folder to which EMDS should be installed. Either accept the default location, C:\EMDS, or specify a new drive or folder name, then press the *OK button*.
7. SETUP.EXE checks for available hard disk space and installs the EMDS application to the specified location if there is adequate disk space, and then creates an EMDS *group* on the Windows 95 *Taskbar* (or a EMDS *group window* in Windows 3.1).

If the drive to which EMDS is to be installed does not have sufficient space, then SETUP.EXE displays a dialog window with a warning. Press the *OK button* in the dialog window to return to step 6. If there are no alternative drives to which EMDS can be installed, you may either press the *Exit button* to abort installation or leave SETUP.EXE running, switch to Windows Explorer, delete folders to create adequate space for the installation, and return to SETUP.EXE to resume installation.

### **Running EMDS Sample Projects**

EMDS is distributed with a set of sample projects. A folder for each sample project is in the \EMDS\SAMPLES folder. ArcView 3.0a or later must be installed on your system to open the sample projects.

To open a sample project:

1. Press the *Start button* on the Windows *Taskbar*.
2. Choose the *Programs item* on the *Start menu*.
3. Choose the EMDS *group item*.
4. Choose the EMDS *application item*.
5. In the EMDS *startup dialog window*, press the *Open button* to display the *Open project dialog window*.
6. Select a sample project from the *list box* and press the *OK button*.
7. When prompted for a password, enter "littlebuddy" without quotes, and press the *OK button*.

Refer to later chapters, "ArcView System" and "Assessment System," for instructions about viewing and running sample assessments.



# Introduction

Ecosystem management decision support (EMDS) version 2.0 is an application framework for knowledge-based decision support of ecological assessments (Reynolds and others 1996, 1997a, 1997b). The EMDS framework is designed to conduct analyses for any geographic scale. The system integrates state-of-the-art geographic information system (GIS) and knowledge-based reasoning technologies in the Microsoft Windows® (hereafter, Windows) environment to provide an analytical tool that is powerful but easy to use. EMDS version 2.0 is not a complete decision support system for the full adaptive management process of ecosystem management; however, it provides a solid foundation on which to build a more comprehensive system.

EMDS is described as an application framework because it is not “ready to run out of the box.” Instead, the system provides a general solution method (for example, a framework) for conducting ecological assessments. To conduct an assessment with EMDS, the user:

1. Constructs a template view that includes all GIS themes that can enter into an assessment.
2. Constructs knowledge bases that describe relations among ecosystem states and processes of interest to the assessment.

EMDS integrates two key applications to support these activities. In particular, NetWeaver provides a knowledge-base development environment, and the EMDS extension to ArcView includes system objects and methods for processing knowledge bases in a GIS application. There are three significant advantages to the EMDS architecture for landscape analysis:

- 
- 
1. Topics included in an assessment, relations among ecosystem states and processes in the knowledge base, and sources of data are completely determined by the user, who has control of problem definition.
  2. Knowledge bases developed for one area are easily adapted to other areas.
  3. Assessment applications can be developed somewhat generically for a larger region, then easily be customized for specific subregions.

Designing and setting up the template view for knowledge-based analysis in ArcView generally require an hour or less, assuming databases for the assessment area already exist. Simple knowledge bases can be built in a few days. More complex knowledge bases may require a few weeks to construct.

### **A Brief History**

The initial analysis phase of system development began in January 1994, with the first meeting of the cooperators. Initial design specifications were completed in January 1995. The initial task order to the Environmental Systems Research Institute (ESRI) and Knowledge Garden, Inc., for the first phase of system implementation was issued in February 1995. Since then, a series of task orders has been issued for incremental development of the system. EMDS version 1.0 was completed in March 1997. Beta testing of EMDS began in December 1996 on three ecoregional assessments being conducted by the USDA Forest Service. EMDS version 2.0 was completed in October 1998.

### **EMDS Features**

Version 1.0 provided support for:

1. Constructing knowledge bases with NetWeaver that describe logical relations among ecosystem states and processes of interest in an assessment.
2. Selecting analysis topics and processing the knowledge base to get a geographic assessment of ecosystem states and processes at the level of landscape features.
3. Evaluating the influence of missing data on the completeness of an assessment.
4. Prioritizing new data acquisition given the influence of data.
5. Performing analyses of alternative scenarios.
6. Basic project management.



Major enhancements in version 2.0 include:

1. Use of multiple GIS themes in a single analysis.
2. Tools for attributing polygons with information about their nearest neighbors.
3. Support for ArcView GRID format.
4. Automatic generation of the Data Catalog at run time, based on attributes of themes contained in template views.
5. ArcView hotlink from EMDS map output to a NetWeaver browser that displays evaluated states of a knowledge base for features selected by the user.

### **Overview of EMDS System Components**

The basic architecture of EMDS and the flow of information among system components are illustrated in figure 1. The EMDS ArcView extension provides the primary system interface in which an assessment team:

1. Defines a template view containing themes for all attributes relevant to an assessment.
2. Defines an assessment area.
3. Reviews geographic attributes of an area as a prelude to assessment.
4. Reviews results of an assessment in maps, tables, graphs, and evaluated knowledge base structure.

The NetWeaver interface (fig. 1) provides a knowledge-base development environment in which an assessment team assembles a knowledge base that describes the logical relations (dependencies) among topics of interest to an assessment, underlying ecosystem states and processes, and data needed to evaluate topics, states, and processes.

The Assessment system includes three subsystems (fig. 1). The basic interface of the Assessment system provides an interface to NetWeaver knowledge bases to:

1. Select topics of interest in the assessment.
2. Define custom sets of analysis topics for future reference.
3. Run an analysis with the NetWeaver engine that processes the knowledge base.
4. Select maps of evaluated ecosystem states and processes to display in ArcView.

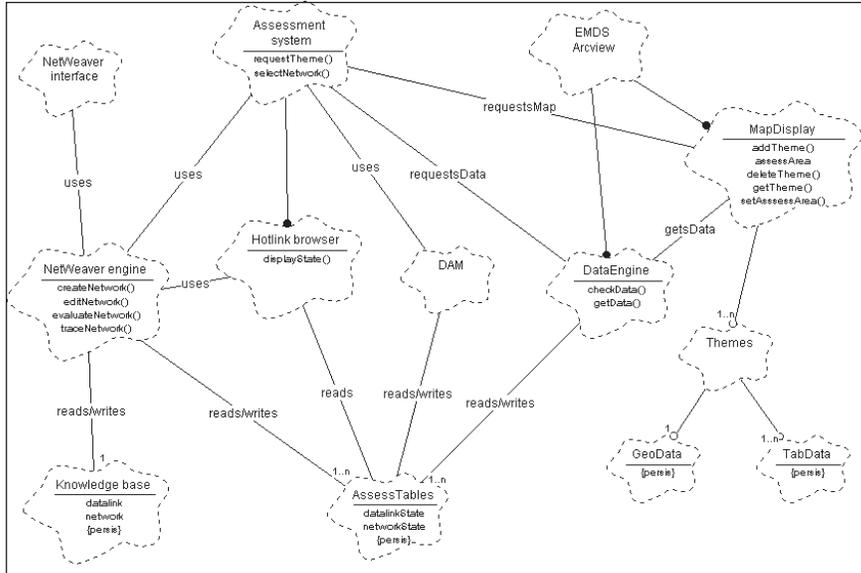


Figure 1—Object diagram of basic EMDS system architecture.

The Data Acquisition Manager (DAM) is the first Assessment subsystem (fig. 1). The DAM prioritizes missing data by using information about the influence of missing data and information gathered from the user about the ease of acquiring missing data. This subsystem is an aid to planning new data collection to improve completeness of an assessment. A variety of maps, tables, and graphs provides useful information about which data are missing, the influence of missing data on completeness of the assessment, and how these data are distributed in the landscape.

The second Assessment subsystem is the Hotlink Browser (fig. 1). After map output for an analysis has been displayed in ArcView, the standard ArcView hotlink tool can be used to select map features for display in the Hotlink Browser. The browser displays the evaluated knowledge base state for the selected feature in a manner similar to the graphic display used in NetWeaver.

The third Assessment subsystem is the Scenario (not illustrated in fig. 1). Scenario provides methods for editing and evaluating copies of input databases to perform “what if” analyses.



## **Key Concepts**

### **Landscape Feature**

The ArcView user guide (Anonymous 1996) states, “A theme is a collection of geographic phenomena that you define. The geographic phenomena are represented in [a] database by geometric elements such as polygons, lines, or points. These are referred to as feature classes.” Individual elements of a theme are features. For example, there may be a theme representing the stream network in a watershed. Individual line segments in this case might correspond to stream reaches (segments within which stream characteristics are considered essentially uniform). A stream reach is an example of a feature in the stream network theme. The concept of landscape features is central to EMDS because analyses performed on an assessment area are performed on each feature in that area.

### **Influence of Missing Data**

In the future, assessment teams may be able to assemble a list of all topics they want to include in an assessment, assemble a list of data requirements needed to address those topics, then find that they have all the required data. In the meantime, assessments routinely need to deal with incomplete data. There may be some missing observations for several to many datum types. There may be no data at all for (possibly) many others.

One solution to the problem of missing data is to tailor an assessment to existing data. This is a poor way to conduct an assessment of environmental phenomena with complex interrelations, however. This type of approach makes it extremely difficult, if not impossible, to infer what is not known about the data that might be relevant and how influential it might be for completing an analysis of ecosystem states and processes. Instead, it is preferable to construct a model that reflects the best understanding of how all states and processes relevant to the assessment are interrelated. The NetWeaver engine incorporated into EMDS uses a simple algorithm to compute the influence of missing data based on the logical structure of the knowledge base, how many states and processes use the information, and at what level the information enters a knowledge base structure. The DAM in EMDS uses information about data influence to help users prioritize new data acquisition needs.

### **Knowledge Base**

Knowledge base applications (Jackson 1990, Waterman 1986) began to appear in significant numbers in natural resource management in 1983 (Davis and Clark 1989). In a more recent survey, Durkin (1993) cataloged more than 100 knowledge



base applications in the environmental sciences. O’Keefe (1985) envisioned an important role for knowledge base systems as components of larger decision support systems in the future.

A knowledge base embodies knowledge about how to solve a problem in some domain of interest. Several different approaches to knowledge-based representation have been developed during the last 30 years (Schmoldt and Rauscher 1995). EMDS incorporates the NetWeaver engine for knowledge-based reasoning (Saunders and others 1990, Stone and others 1986). This system implements a knowledge base as hierarchies of dependency networks. By itself, a knowledge base does not actually do anything. The knowledge base that an assessment team constructs with NetWeaver is best thought of as a metadatabase. It is used to interpret data processed by the inference engine. For additional discussion about the structure of NetWeaver knowledge bases, see the “NetWeaver System” chapter in this manual and the NetWeaver user guide (Reynolds 1999).

### **Knowledge-Based Reasoning**

Knowledge-based reasoning (or equivalently, symbolic reasoning) is a general modeling methodology in which phenomena are described in terms of abstract entities and their logical relations to one another. There are two basic reasons for using knowledge-based reasoning:

1. The entities, or their relations, involved in the problem to be solved are inherently abstract so that mathematical models of the problem are difficult to formulate.
2. A mathematical solution is possible in principle, but current knowledge is too imprecise to formulate.

Both cases are quite common in environmental sciences. The first case naturally arises when the nature of the problem involves inherently abstract “things.” Such problems may be easier to solve with logic. The second case arises frequently because, particularly when dealing with natural systems, there is an almost unlimited number of relations of potential interest. Agencies, academia, and others have developed numerous mathematical models to describe some of the important relations for ecosystem management, but many have not been studied in adequate detail to provide sufficiently general mathematical solutions. There often is a wealth of human experience in these same institutions, however, that can be drawn

upon to develop useful, more qualitative, knowledge-based models to guide decisionmaking. One other valuable aspect of symbolic reasoning that makes it ideal for use in ecological assessment is that such systems can reason with incomplete information. The NetWeaver engine provides partial evaluations of ecosystem states and processes based on available information, and provides useful information about the influence of missing data that can be used to improve completeness of an assessment.

### **Inference Engine**

There are two basic parts of a knowledge-based reasoning system:

1. The knowledge base itself, which defines the entities of the problem domain, their relations to one another, and perhaps some of their states.
2. The inference engine, which operates on the knowledge base and external data sources (performs the knowledge-based reasoning) to draw conclusions about the state of the system.

In EMDS, the user builds a knowledge base in NetWeaver that describes the problem domain. Performing an assessment entails running the inference engine on the knowledge base.

### **Fuzzy Logic**

Basic concepts of approximate reasoning with fuzzy logic were first presented by Zadeh (1965, 1968). Subsequent concept papers (Zadeh 1975a, 1975b, 1976) elaborated on the syntax and semantics of linguistic variables, laying the foundation for what has now become a significant new branch of mathematics. Fuzzy logic focuses on quantification of set membership and associated set operations. Formally (Kaufmann 1975),

let  $\mathbf{E}$  be a set, denumerable or not, and let  $x$  be an element of  $\mathbf{E}$ . Then a fuzzy subset  $\mathbf{A}$  of  $\mathbf{E}$  is a set of ordered pairs  $\{x, \mu_{\mathbf{A}}(x)\}$ ,  $\forall x \in \mathbf{E}$ , in which  $\mu_{\mathbf{A}}(x)$  is a membership function that takes its values from the set  $\mathbf{M} = [0, 1]$ , and specifies the degree of membership of  $x$  in  $\mathbf{A}$ .

Fuzzy set theory is a generalization of boolean set theory, and most boolean set operations have equivalent operations in fuzzy subsets (Kaufmann 1975, p. 11).

Application of fuzzy logic to natural resource science and management is still relatively new. General areas of application include classification in remote sensing (Blonda and others 1996), environmental risk assessment (Holland 1994), phytosociology (Moraczewski 1993a, 1993b), geography (Openshaw 1996), ecosystem



research (Salski and Sperlbaum 1991), and environmental assessment (Smith 1995, 1997). More specific applications include catchment modeling (Anonymous 1994), cloud classification (Baum and others 1997), evaluation of plant nutrient supply (Hahn and others 1995), soil interpretation (Mays and others 1997, McBratney and Odeh 1997), and land suitability for crop production (Ranst and others 1996).

The EMDS design team selected the NetWeaver knowledge-base engine for integration into EMDS because of its implementation of fuzzy logic-based reasoning. Compared to classical rule-based systems (Waterman 1986), knowledge representation for problem specification using fuzzy logic is more precise, compact, and efficient. The team was convinced, moreover, that the combination of propositional logic networks with fuzzy logic-based reasoning, as implemented in NetWeaver, would make knowledge-based solutions to ecological assessments far more feasible than classical methods owing to the implementation of object-based design (Booch 1994) and consequent support for evolutionary design of complex system specifications (Gall 1986).

# EMDS Online Help

The EMDS Help system is accessed from the *Assessment menu* of ArcView. In version 2.0, Help is implemented in hypertext markup language (HTML). Selecting the *EMDS Help menu item* starts the web browser configured for use with EMDS.

The display area is divided into a contents frame on the left and a topic display frame on the right. Contents items preceded with a + symbol are expandable.

- Click on the + symbol in front of an item to expand the outline for that topic.
- Click again (now a - symbol) to collapse.

To view a topic displayed in the contents:

- Click on the item to highlight it, then press the *Display page button*, or
- Double click on the item.

Blue text in the body of a text explanation indicates a hyperlink (displayed in blue by default). Click on a hyperlink to go to the indicated topic or figure. Text links are displayed in the same right frame. Use the browser's *Back button* to return to the previous topic. Links to figures are displayed in a new browser window. Close the window when you are finished viewing a figure.



# ArcView System

## ArcView Features

The EMDS ArcView extension adds an important additional *menu* to the standard ArcView *menus* for EMDS-specific functions, but all other aspects of the ArcView interface remain unchanged (fig. 2). ArcView makes basic GIS technology accessible to a broader audience than the Arc GIS development system, which requires a significant amount of training to gain proficiency. ArcView is still a powerful and sophisticated application, however, that requires at least 2 to 3 hours for user proficiency. For documentation about use of standard ArcView features in EMDS, see the ArcView users guide (Anonymous 1996). Users new to ArcView will want to view the ArcView tutorial.

## ArcView and EMDS Projects

The EMDS ArcView extension is one of the primary components of the EMDS system (fig. 1). The extension adds additional objects and methods to ArcView to support knowledge base processing in the GIS environment. ArcView is organized around the concept of a project. It will be useful to review the help topics, “projects” and “project window,” in the ArcView Help system for a basic orientation to the ArcView interface if you are not familiar with the basic operation of ArcView. ArcView is central to the operation of EMDS; applications built with the EMDS ArcView extension are referred to as EMDS projects.

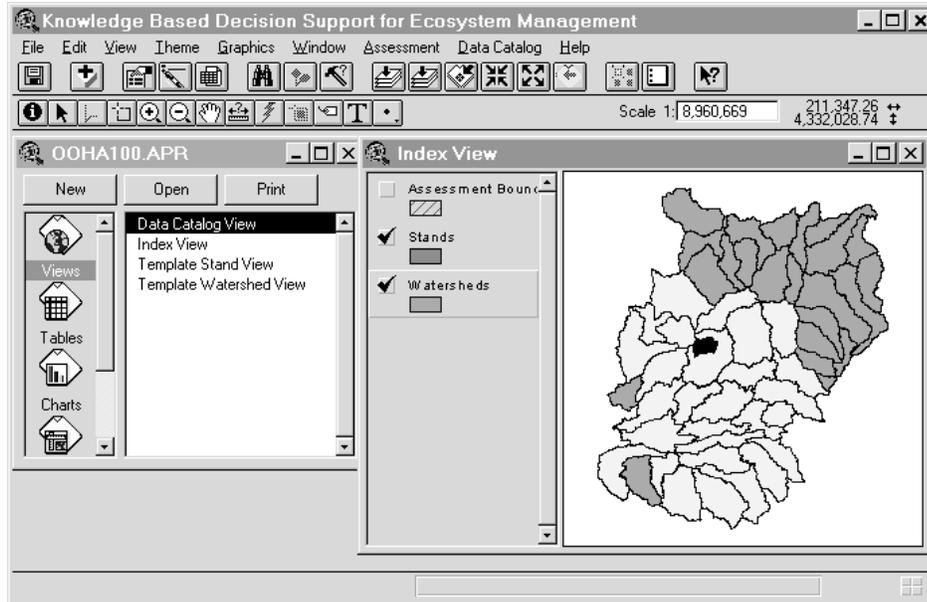


Figure 2—ArcView interface with custom assessment menu added by EMDS.

There is a basic hierarchical structure to EMDS:

- A real-world assessment (that is, the total process conducted by an assessment team) may consist of multiple EMDS projects.
- A single EMDS project may contain multiple assessments.
- A single EMDS assessment may contain multiple analyses.

### Multiple EMDS Projects

An actual assessment may involve analyses at multiple geographic scales. Although a single EMDS project is capable of storing all data references for all scales of analysis for an actual assessment, users may find it useful to set up a separate EMDS project for each major geographic scale of analysis. The main advantage to separate EMDS projects by geographic scale is that two or more assessment subteams may work in parallel on different scales of analysis.

### Multiple EMDS Assessments Within an EMDS Project

An EMDS assessment is always associated with a specific landscape unit or a set of landscape units. A single EMDS project may contain multiple assessments. An EMDS assessment can, but does not need to, have a one-to-one relation to an actual assessment (that is, one being conducted by an assessment team).



An EMDS assessment is defined by selecting an analysis area in the *Index view* within ArcView (fig. 2). Definition of the analysis area is flexible because the area can be any collection of landscape features within a given *theme* of the *Index view*, and the features need not be contiguous. Multiple assessments within an EMDS project are needed under two conditions:

1. The actual assessment includes different scales of analysis. Each scale of analysis requires at least one EMDS assessment.
2. Within a given scale of analysis, there are two or more sets of landscape units for which you want to conduct separate analyses.

### **Multiple Analyses Within an EMDS Assessment**

Typically, multiple analyses are conducted on a given assessment area, because each NetWeaver knowledge base is designed to evaluate attributes associated with a specific landscape feature or a specific set of features. For example, one analysis may be based on attributes of stands, while another in the same EMDS assessment is based on attributes of counties. The two scales are approximately the same, but each analysis focuses on a different type of landscape feature as the unit of analysis.

As of version 2.0, analyses of knowledge bases now can use data from multiple themes, given certain compatibility requirements among theme types. Knowledge bases requiring different combinations of themes still might result in the need for different analyses.

### **EMDS Data Engine**

The Data Catalog is an ArcView table that stores references to numerous, diverse types of data, including data from different themes. The Data Catalog concept implemented in version 1.0 (a persistent data lookup table created by the user) has been replaced by the Data Engine in version 2.0. The Data Catalog still exists as a data structure in version 2.0, but now it is assembled during analysis by the Data Engine from the contents of the *Template view* that has been designated for the assessment. Each record in the Data Catalog identifies:

1. The name of the data link as defined in the knowledge base.
2. The name of the GIS theme with which the variable is associated.
3. The ArcView name for the variable.
4. The name of the field in the attribute table associated with the theme.
5. The file name of the attribute table.

6. Directory information that specifies the location of the attribute table on the local system or on a local area network.

Attribute tables may be in any database format supported by Microsoft Open Database Connectivity (ODBC), including Microsoft Access, Borland FoxPro, dBASE, and ORACLE. For a complete list of ODBC-supported database formats, see the Microsoft ODBC documentation.

See the section, “Knowledge Base Processing,” below, for an explanation of how the Data Catalog is used by the NetWeaver engine to evaluate a knowledge base.

## Views

In ArcView, a *view* is a window that displays thematic maps of geographic information. Each *view window* is subdivided into a *map pane* and a *table of contents pane* (fig. 2). A theme within the *map pane* is activated (turned on) or deactivated (turned off) by clicking on its name in the *table of contents*. An activated theme appears slightly raised in the table of contents. ArcView Help provides extensive documentation about standard ArcView operations that apply to *views*.

This section briefly introduces three EMDS-specific *views* that a user interacts with while setting up and conducting an assessment. Later sections in this chapter provide specific instructions about how to create these *views*.

### Index View

After an EMDS project has been set up, the *Index view* of a project is automatically displayed when the project APR file is opened (fig. 2). The *Index view* displays the geographic extent of a region and the boundaries of potential assessment areas within that region. Multiple assessment boundary themes can be included in the *Index view* to define different scales of assessment within the region. For example, a single *Index view* might contain a regional boundary, physiographic province boundaries, and watershed boundaries.

### Template View

The default set of themes that appears in the *Assessment view* (see the following subsection) is determined in the *Template view* (fig. 3). Multiple *Template views* can be defined within an EMDS project. There are three basic choices:

1. One *Template view* that applies to all scales of assessment.
2. One *Template view* for each scale of assessment.
3. Multiple alternative *Template views* for any given scale.

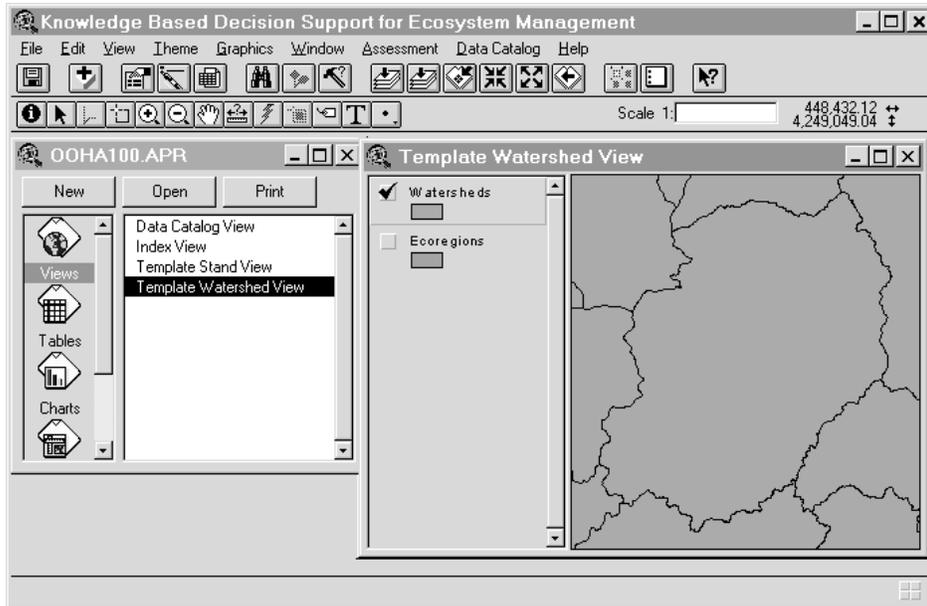


Figure 3—An *EMDS Template* view determines which themes are displayed in the *Assessment* view.

When a new assessment is first created, ArcView prompts to select the *Template view* (from a list of the available *Template views*) to associate with the new *Assessment view*. Once an assessment has been saved, the *Template view* originally assigned to it becomes permanently associated with that assessment. The Data Engine uses the contents of the *Template view* associated with an assessment to construct a Data Catalog during analysis. Consequently, a *Template view* must contain all the themes that have attribute data needed by a knowledge base for an analysis.

### Assessment View

After creating a new assessment or opening an existing assessment from the ArcView *Assessment menu*, a new *view* is opened for the selected assessment area based on the *Template view* selected (fig 3.). The *Assessment view* has three primary functions in EMDS:

1. Before conducting an assessment of an area, the *Assessment view* can be used to become familiar with basic landscape attributes of the area for problem orientation.
2. Once an assessment has been performed, evaluated ecosystem states and processes can be examined in the *Assessment view*.

3. The *Assessment view* also can be used to examine the distribution of missing data and its relation to road systems (for example) as an aid to deciding how difficult it will be to acquire missing data and how to prioritize new data acquisition.

The default set of themes that appears in the *Assessment view* is determined in the *Template view*. However, an *Assessment view* can be customized by the addition of new themes or the deletion of default assessment themes. See theme topics in ArcView Help for further information.

## Setting Up an EMDS Project

### Creating a Base ArcView Project

To create an EMDS project, first create a standard ArcView project that contains a set of views and themes to import into the EMDS project. Below, this standard ArcView project is referred to as the base project because it will be the basis for creating an EMDS project.

1. Start ArcView 3.0a (or later version).
2. In the empty ArcView project (see following sections for details about each of the three steps).
  - a. Create an *Index view*.
  - b. Create a *Template view*.
  - c. Assign ArcView aliases.
3. Save the ArcView project (this is the base ArcView project).

*Creating an Index view*—The *Index view* contains one or more themes from which a user can select a specific assessment area for analysis. To create an *Index view* in ArcView:

1. Highlight the *Views icon* in the ArcView project window.
2. Select the *New button* at the top of the ArcView project window to create “view1.”
3. Choose the *Rename view1 menu item* from the *Project menu*.
4. In the dialog window that opens, type “*Index view*” to rename the new view.
5. With the *Index view* window open and active (highlighted), choose the *Add theme menu item* from the *View menu*.

6. In the dialog window that opens, enter the name of an existing theme that delineates possible assessment areas as features.

To move additional themes to the *Index view*, repeat steps 5 and 6.

*Creating a Template view*—A *Template view* defines the default set of GIS themes that will be available in the *Assessment view* when a new assessment is started or an existing assessment is opened. The *Template view* must contain all the themes that contain attribute data needed by a knowledge base for an analysis. To create a new *Template view*:

1. Highlight the *Views icon* in the ArcView project window.
2. Select the *New button* at the top of the ArcView project window to create “view1.”
3. Reselect the ArcView project window to make it the active window and choose the *Rename view1 menu item* from the *Project menu*.
4. In the dialog window that opens, type “*Template view - X*” to rename the new view, where X indicates a brief descriptor to distinguish among multiple *Template views*.
5. With the new *Template view* window open and active (highlighted), choose the *Add theme menu item* from the *View menu*.
6. In the dialog window that opens, enter the name of an existing theme that delineates possible assessment areas as features.
7. Optionally, to see how themes will display, use the ArcView selection tool to select an example assessment area and zoom the display to the extent of the selected feature.
8. Repeat steps 5 and 6 to add themes that might be useful to have in the *Assessment view*.

*Assigning ArcView aliases*—In this step, the names of data links in a NetWeaver knowledge base are associated with data table fields. The *Template view* may contain one or more themes. Each theme displayed in the view’s *table of contents* has a table associated with it that contains attribute data associated with the features of the theme. The field name in the table is the name of the column in the data source. The field alias is the corresponding name for the NetWeaver data link.



To set up the association between NetWeaver data link names and ArcView theme field aliases:

1. If necessary, select the *Views icon* in the ArcView project window to display the available *views*.
2. Select the appropriate *Template view* in the ArcView Project window.
3. Select the *Open button* at the top of the ArcView Project window to open the *Template view*.
4. Activate the theme in the *Template view's* table of contents whose fields include data to be accessed by NetWeaver.
5. Press the *Open theme table button* on the ArcView *Button bar*.
6. Choose the *Properties menu item* from the *Table menu* on the ArcView *Menu bar*.
7. Locate the fields within the open table that correspond to the data inputs to be associated with NetWeaver data links. These appear in the column labeled "Field." Be sure that the name of the NetWeaver data link entered in the alias field is exactly the same as it appears in NetWeaver, including case, spaces, and any punctuation.
8. In the column labeled "Alias," enter the corresponding NetWeaver data link name.
9. Close the table.
10. Repeat steps 4 through 9 for each theme in the *Template view* that contains data fields used by the knowledge base.

EMDS version 2.0 allows an assessment to use multiple themes for analyses because the Data Engine generates a Data Catalog from the *table of contents* of a *Template view* when an assessment area is first defined. The Data Catalog for knowledge base processing can be assembled from the following combinations of themes in the *table of contents* of a *Template view*:

1. Any number of polygon themes can be joined by intersection.
2. One line theme and any number of polygon themes. Polygons are first joined by intersection with one another, then the new polygon theme generated by intersection is joined to the line theme.
3. One point theme and any number of polygon themes. Polygons are first joined by intersection with one another, then the new polygon theme generated by intersection is joined to the point theme.

A single *Template view* may contain multiple line and point themes. However, attempts to specify multiple line or point themes as data sources in a given assessment will generate an error at the time of Data Catalog creation because multiple themes of these types cannot be joined. A theme becomes a data source for analysis when it contains a NetWeaver alias identifier.

### **Creating a New EMDS Project**

1. Choose the *EMDS* item under the *EMDS program group* on the Windows 95 or Windows NT *Taskbar*.
2. In the *Startup application window*, press the *New button* or choose *New* from the *Project menu*.
3. Complete the *edit lines* in the *New project dialog window* to specify a short name for the project (this name is displayed in the *Project list box*, discussed below in "Managing EMDS Projects"), a longer descriptive name for the project, the full path name for the new project folder (directory), and an optional password for the project.
4. Press the *OK button* in the *New project dialog window*.

When step 4 is completed, the Startup application creates the new project folder, copies all folders from the \EMDS\TEMPLATES folder to the new project folder, and creates a custom EMDS.INI file in the new project APR folder. Information entered at step 3 also is added as a new record to \EMDS\PROJECTS\PROJECT.RAP which maintains basic information about all EMDS projects.

### **Completing Setup of a New EMDS Project**

1. Choose the *EMDS item* under the *EMDS program group* on the Windows 95 or Windows NT *Taskbar*.
2. In the EMDS Startup application, press the *Open button* or choose *Open* from the *Project menu*.
3. In the *Open project dialog window*, select the project to open from the *list box* and press the *OK button* to open the selected EMDS project.
4. With the ArcView *Project window* active, choose *Import* on the ArcView *Project menu* to import the base ArcView project into the new EMDS project. In the *Import dialog window*, navigate to the folder that contains the base ArcView project, select the project, and press the *OK button* to import it into the EMDS project. The *index view* and any *Template views* from the base project now have been imported into the EMDS project.

5. In the *Project window*, highlight the *Index view* that contains the themes from the base ArcView project to be used in the EMDS project. Press the *Open button* to open the *view*. Activate the themes to be copied in the *Table of contents* of the *Index view*, and choose *Copy themes* on the *Edit menu*.
6. Highlight the *Assessments Index view* in the *Project window*, open the *Assessments Index view*, and choose *Paste* on the *Edit menu*.

### **Neighborhood Attribute Tool**

Once an ArcView base project has been imported into an EMDS project, the *Neighborhood attribute item* can be selected from the *Assessment menu* to associate simple statistics on attributes of neighboring polygons with the features in a selected theme in a *Template view*. The neighborhood attribute tool iterates through the list of features in the selected theme, treating each feature as the current subject polygon, and computing a selected statistic on a selected data field in all neighboring polygons. Neighbors of a subject polygon are those polygons whose centroids are within a specified radial distance from the centroid of the subject polygon.

To use the neighborhood attributes tool:

1. Open the *Template view* containing the theme to be processed by the neighborhood attribute tool.
2. Select the theme in the *view's table of contents* to make it the active theme in the *view*.
3. Select the *Neighborhood attributes item* from the *Assessment menu* to open the *Neighborhood attributes dialog window* (the *menu item* is only enabled on the *Assessment menu* after a theme has been activated in step 2).
4. Fill in the *edit line* for the ArcView data field name to assign to the statistic.
5. Fill in the *edit line* for radial distance that specifies the neighborhood of each subject polygon.
6. Select the name of the data field in the *Neighbor attribute list box* that contains the neighbor attribute to associate to each subject polygon.
7. Select the statistic to apply from the *Statistic drop-down list box*.
8. Press the *OK button* to close the *dialog window* and begin processing the polygons.

After statistical processing of the theme has been completed, the theme now contains the new data field with the name assigned in step 4. Repeat steps 3 through 8 to create as many new data fields with neighborhood attributes as necessary. To include the newly created data field(s) in subsequent analyses, follow the procedures outlined in the section, "Assigning ArcView aliases," above.

### **Using EMDS with GRID and Spatial Analyst**

EMDS version 2.0 can process themes with GRID data, greatly extending the spatial operations that potentially can be performed in EMDS. In particular, if ESRI's Spatial Analyst extension is available on the same computer as EMDS, Spatial Analyst may be added as an extension to EMDS. A detailed discussion of Spatial Analyst and its GRID processing capabilities are beyond the scope of this manual.

For a more thorough treatment of spatial operations available in Spatial Analyst, see Anonymous (1997).

### **Managing EMDS Projects**

EMDS Startup is an EMDS helper application that provides basic project management for EMDS projects. Its most important functions are creating new EMDS projects and opening existing projects as described in the previous two sections. Although it is possible to setup new projects and open them from Windows Explorer in Windows 95 or Windows NT, it is strongly recommended that you use EMDS Startup to manage these processes because the application takes care of setting up and managing INI files used by EMDS.

EMDS Startup provides the following additional functions for project management:

- Setup and maintenance of project passwords.
- Adding project folders for projects originally created on a different computer.
- Deleting projects.

### **ArcView Assessment Menu**

This section covers the custom menu added to ArcView for EMDS applications (fig. 2). For documentation about standard ArcView features of EMDS, see the ArcView user guide (Anonymous 1996) or online documentation in ArcView Help. The following menu choices are available on the *Assessment menu* (fig. 2):

- *New Assessment* opens a dialog window to enter a name for a new assessment. See the section, "Assessment Management," "Creating a New Assessment" for additional information.

- *Open Assessment* opens a *dialog window* to select the name of an existing assessment to open. Only one assessment may be open at any given time. If an assessment is opened, and there is already one open, the latter is closed before opening the next one.
- *Close Assessment* closes the currently loaded EMDS assessment. If no assessment has been opened, this *menu item* has no effect.
- *Save Assessment* saves the current state of all assessment files associated with the open assessment.
- *Show Assessment Window* provides initial entry into the EMDS Assessment system.
- *Neighborhood attribute tool* provides basic support for generating statistics on neighbor attributes that can be associated with polygons and included in analyses.

# NetWeaver System

NetWeaver is a knowledge base development system that has been incorporated into EMDS. It provides a framework for constructing knowledge bases. The NetWeaver user guide (Reynolds 1999) and the NetWeaver Help system provide extensive documentation about how to use the system to construct knowledge bases for environmental assessment. This section summarizes basic attributes of NetWeaver knowledge base architecture and how NetWeaver knowledge bases are processed in EMDS.

## Relation of Analysis Topics to NetWeaver Networks

A NetWeaver knowledge base is a hierarchy of dependency networks (fig. 4). Each network corresponds to a topic of interest in the problem domain represented by the knowledge base. There is a one-to-one correspondence between networks in a NetWeaver knowledge base and topics that are available to be included in an analysis within the Assessment system.

## NetWeaver Engine

The NetWeaver engine is a Windows dynamic link library (DLL) developed by Rules of Thumb, Inc. (North East, PA). The NetWeaver knowledge base development environment is an interface to the engine that is used for constructing knowledge bases (fig. 5). The EMDS Assessment system also is an interface to the NetWeaver engine; under the direction of the Assessment system, the engine processes the hierarchy of dependency networks specified by the knowledge base (fig. 6) to produce an assessment of ecosystem states and processes.

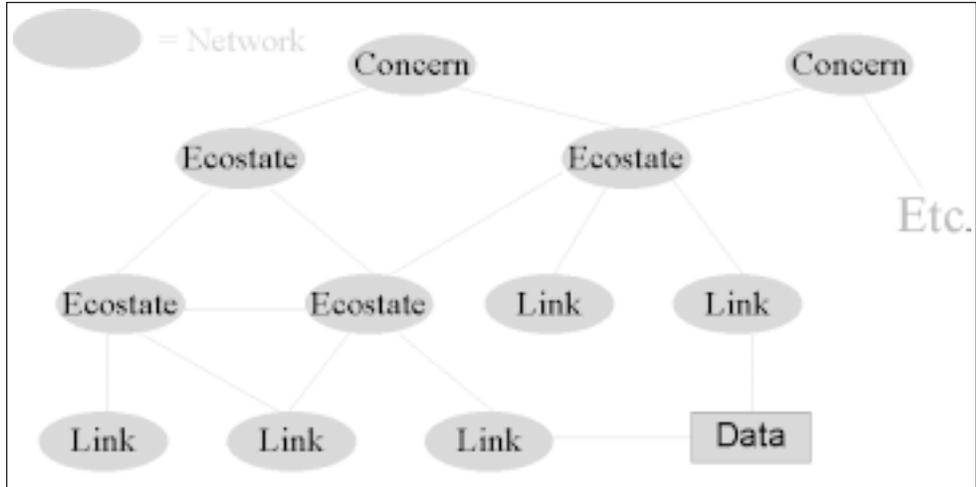


Figure 4—The basic structure of a NetWeaver knowledge base is a hierarchy of dependency networks.

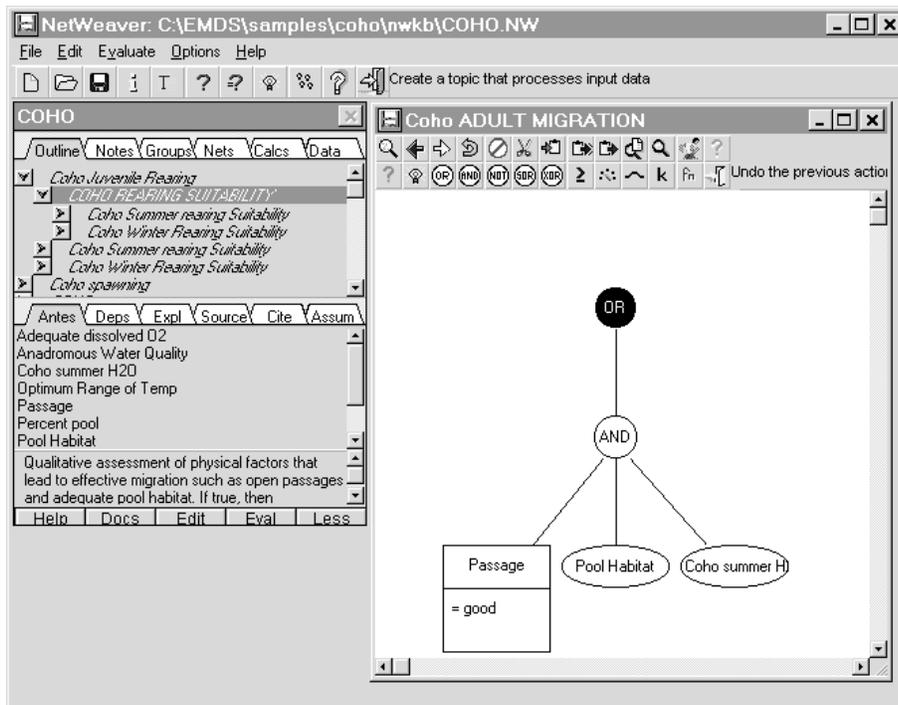


Figure 5—The NetWeaver knowledge base development environment.

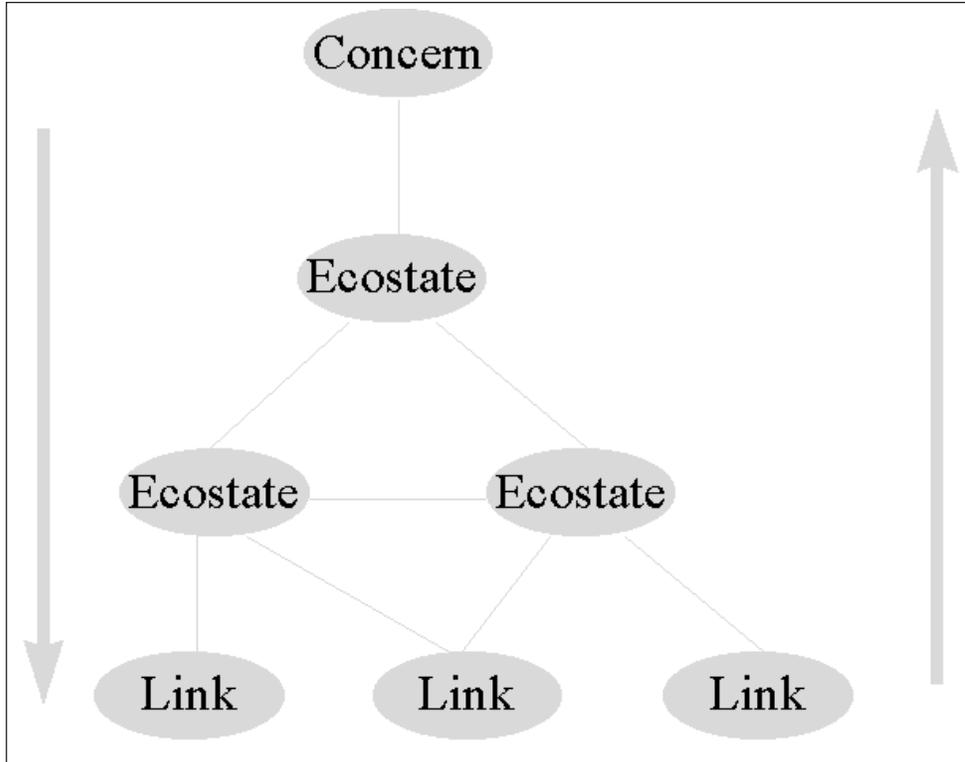


Figure 6—NetWeaver knowledge base processing.

## NetWeaver Knowledge Bases

NetWeaver knowledge bases are object-based. There are two basic types of object: the **dependency network** and the **data link** (fig. 4), each of which is represented in the network structure by a programming object that has both state and behavior.

### Dependency Networks

A knowledge base represents knowledge about how to solve a problem (in this case, how to evaluate topics of interest in an assessment) in terms of the topics of interest in the problem domain, and the relations (dependencies) among these topics. Each dependency network in a NetWeaver knowledge base represents a proposition about the condition of some ecosystem state or process.

*State*—The key state variable of a dependency network is its truth value which expresses the degree to which evidence from antecedent dependency networks



and data links support or refute the proposition. Logically, network A is antecedent to network B, if B depends upon A, because network A must be evaluated before network B can be evaluated.

*Behavior*—The basic function of a dependency network is to evaluate the truth of its proposition. NetWeaver dependency networks have three basic behaviors related to this function:

1. They query their antecedents to determine the latter's state.
2. They evaluate their own state, given the state of their antecedents.
3. They inform higher level networks that depend on them about their state.

### **Data Links**

A data link is an elementary dependency network with slightly modified behavior.

*State*—Like a dependency network, a data link may evaluate to a truth value, given a data input. A data link also may hold an actual data value that is subsequently transformed by mathematical operations defined for a calculated data link.

*Behavior*—

1. When using the NetWeaver development environment, data links prompt the user for data input. When an analysis is being performed within the Assessment system in EMDS, data links request data from the system, which passes the request to the Data Engine in ArcView (fig. 1).
2. On receipt of data, data links evaluate their state, given the data input (simple data links), or pass the data value to a special data link that performs some transformation of input data (calculated data link).
3. They inform higher level networks that depend on them about their state.

### **Truth Values**

The truth value is the basic state variable of both dependency networks and data links. It expresses an observation's degree of membership in a set that represents some concept, such as good gravel cover in spawning beds or good elk habitat. Evaluations of degree of set membership are quantified in the semantics of fuzzy logic (Zadeh 1965, 1968, 1975a, 1975b, 1976, 1986, 1992, 1995).

Data links are frequently used to read a datum (for example, percent gravel cover) and evaluate its degree of membership in a concept that is quantified in a fuzzy argument (an argument that quantifies fuzzy set membership). Thus, in a data link the argument is a mathematical statement of a proposition. Some simple examples include:

- If the datum fully satisfies the argument, then the truth value of the data link is 1 (true).
- If the datum is fully contrary to the argument, then the truth value of the data link is -1 (false).
- If the datum partially satisfies the argument, then the truth value of the data link is in the open interval (-1, 1). Note that negative truth values greater than -1 do not connote negative truth. Rather, such values connote low membership.
- If the datum is not known, then the truth value of the data link is 0 (undetermined).

Interpretation of truth values within networks must be treated more generally, because the truth value of a network may depend on several to many fuzzy logic operators. Simple examples related to the two key fuzzy logic operators, AND and OR, are:

- If **all** logical paths antecedent to a fuzzy AND operator fully support the AND relation, then the truth value of the operator is 1 (true).
- If **any** logical path antecedent to a fuzzy AND operator is fully contrary to the AND relation, then the truth value of the operator is -1 (false).
- If **any** logical path antecedent to a fuzzy OR operator fully supports the OR relation, then the truth value is 1 (true).
- If there is no evidence for or against an AND or OR relation, then the truth value of either operator is 0 (undetermined).

As with data links, networks also may evaluate to partially true. Two conditions that result in this condition in NetWeaver:

1. One or more data items are missing and cannot be supplied, and therefore contribute a value of 0 to a fuzzy AND.
2. One or more data items that influence the truth value of a dependency network have been evaluated against a fuzzy argument and been found not to have full membership in the fuzzy set defined by the fuzzy argument.

## Knowledge Base Processing

Knowledge base processing in EMDS is performed by the NetWeaver engine. Data input to the engine is mediated by the Assessment system, and the Data Engine in ArcView. The interaction of these three system components is summarized as follows (fig. 1):

1. When the *Data req(uirements) button* is pressed in the Assessment system, the NetWeaver engine traces the dependencies for the top-level networks that have been selected for analysis down through the structure of the knowledge base to find the data links required to conduct an analysis (fig. 6).
2. The NetWeaver engine returns a list of required data links to the Assessment system.
3. The Assessment system passes the list of data requirements to the Data Engine. The latter ArcView subsystem is a custom component of ArcView whose operation is transparent to the user.
4. The Data Engine uses the list of data requirements to look up appropriate database field name cross-references in the Data Catalog and to determine the status of the fields (present in or absent from the Data Catalog). A status table is assembled in ArcView and automatically displayed.
5. When the Run button is pressed in the Assessment system, the latter requests that the ArcView Data Engine retrieve the data from the appropriate fields in the appropriate databases.
6. The Data Engine makes the appropriate queries to the databases, and assembles the returned data into an input data table that is processed by the data links of the knowledge base.
7. Evaluations cascade upward through the hierarchy of dependency networks until the top-level networks that initially were selected for analysis have been fully evaluated (fig. 6).

# Assessment System

## Assessment Management

Whereas activities in ArcView are organized around the concept of a project, activities within an EMDS project are organized around the concept of an assessment. Assessments can be conducted at any geographic scale. Each assessment is associated with a specific assessment area that is selected in the ArcView *Index view* (fig. 7). The scale of the assessment and its related analyses also are defined.

The main folder for an EMDS project contains a \PROJECTS subfolder when the project is created (see “Creating new EMDS Project” in the “ArcView System” chapter). Each time a new assessment is created from the ArcView *Index view*, EMDS creates a new subfolder (for example, \PROJECT\_A) in the \PROJECTS subfolder with a unique user-supplied name. Multiple assessments can be associated with a single geographic area, allowing the area to be partitioned into two or more separate assessments if desired. This might be desirable if, for example, two or more teams were working somewhat independently on different aspects of an assessment. Multiple EMDS assessments within an EMDS project are required under two conditions:

1. The actual assessment includes different scales of analysis. Each scale of analysis requires at least one EMDS assessment.
2. Within a given scale of analysis, there are two or more sets of landscape units for which separate analyses are desired.

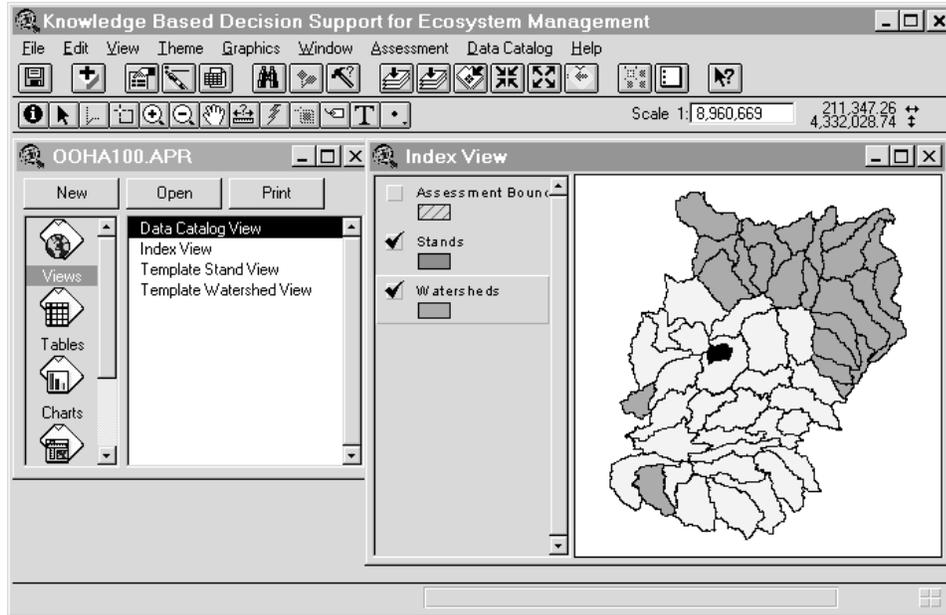


Figure 7—Defining a new assessment in the *Index view*.

### Creating a New Assessment

1. Activate the appropriate theme in the *Index view* (fig. 7).
2. Select the assessment area within the theme with the ArcView *selection tool*.
3. Choose *New Assessment* from the ArcView *Assessment menu*.

If more than one *Template view* exists for the EMDS project, then a *dialog window* is displayed following step 3. Select the appropriate *Template view* from the list to use for the assessment and press the *OK button* to complete the creation process. At step 2 the ArcView *selection tool* can be used to select multiple contiguous features within the active theme in the *Index view* to define an assessment area as a collection of areas (fig. 7).

### Opening an Existing Assessment

1. Choose *Open Assessment* from the ArcView *Assessment menu* (fig. 7).
2. A *dialog window* displays the names of assessments that have been created within the EMDS-ArcView project in a *list box*.
3. Click to highlight the name of the assessment to open in the *list box*.
4. Press the *OK button*.

## **Saving an Assessment**

Saving an assessment saves the current state of the *Assessment view*. If an analysis has been run, and any themes displaying results have been generated for that analysis, then the *Assessment view* is saved with the new results themes included in its table of contents, and these themes will be available the next time that the assessment is opened. To save an assessment, choose *Save Assessment* from the ArcView *Assessment menu*.

## **Assessment System Components**

The EMDS Assessment system is an interface to the NetWeaver engine and consists of three main subsystems (fig. 1).

- The Hotlink Browser provides graphical displays of the evaluated states of a knowledge base for landscape features that have been selected in themes generated by an analysis and displayed in the *Assessment view*.
- The DAM assists with setting priorities for missing data.
- Scenario lets the user alter data inputs and override default knowledge base evaluation to explore alternative scenarios.

Most control of these subsystems is achieved through the *Assessment button bar* or the *Assessment menu bar*, which are documented in the following two subsections (fig. 8). The operation of each subsystem is detailed in the three subsections following description of the assessment interface.

### **Instantiated Knowledge Bases**

EMDS knowledge bases created with NetWeaver are not modified directly by the Assessment system. An analysis adds specifications to the knowledge base, but these specifications are stored separately from the knowledge base in analysis files.

Specifications for an analysis include which topics have been selected for analysis, topics that are to be ignored, and values applied to specific topics. An instance of the knowledge base is created by applying the specifications to a copy of the knowledge base. The knowledge base then is said to be instantiated.

### **Assessment Interface**

The Assessment system is the basic interface to the NetWeaver knowledge base engine within EMDS and provides methods to:

1. Start a new analysis or load an existing analysis.
2. Select topics to be included in an analysis.

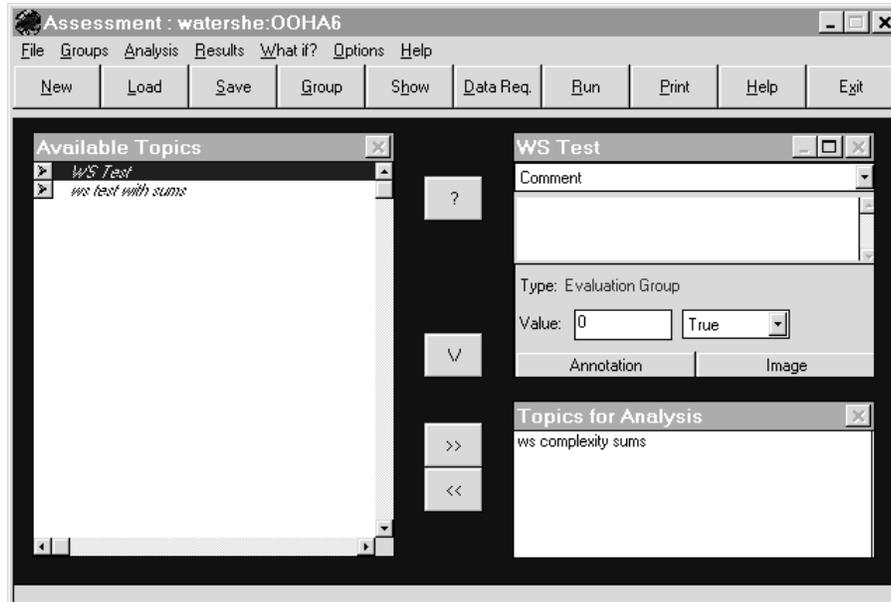


Figure 8—Assessment system interface.

3. Select topics to define custom sets of analysis topics for future reference.
4. Run an analysis with the NetWeaver engine to process a knowledge base.
5. Display maps of evaluated ecosystem states and processes in ArcView.
6. View evaluated states of the knowledge base for landscape features selected in analysis themes displayed in the *Assessment window*.
7. Create alternative scenarios by modifying data inputs to and structure of the knowledge base.

#### Assessment Button Bar

- The function of each button (fig. 8) also is replicated on the *Assessment menu bar*. Most window objects discussed in this section also are illustrated in figure 8.
- *New analysis* loads an uninstantiated version of the currently loaded knowledge base. It duplicates the function of *New analysis* on the *File menu*.
- *Open analysis* loads an existing analysis (instantiated knowledge base) and initializes the knowledge base to its previously evaluated state. It duplicates the function of *Open analysis* on the *File menu*.

- *Save* saves the current state of an analysis (instantiated knowledge base). If an analysis has not been run yet, the *Save button* must be pressed before pressing the *Data req(uirements) button*, otherwise an error message is displayed informing you to save the analysis first. An analysis can be saved after selecting a number of topics, then reloaded later to continue selecting additional topics; however, any change in knowledge base state resulting from additional topic selections or topic deletions requires resaving before getting data requirements. As a security measure, each set of modifications of this type requires a new analysis name. This helps assure that analyses are not overwritten inadvertently. It duplicates the function of *Save analysis* on the *File menu*.
- *Group* defines the current set of selected topics (networks in NetWeaver terminology) in the *Available topics window* as a custom group for future use in the present analysis. A *dialog window* opens, requesting a name for the group. On closing the *dialog window*, the group is added to the list of topics in the *Available topics window*. It duplicates the function of *Make group* on the *Group menu*.
- *Show* toggles display of the topic hierarchy in the *Available topics window* between display of all topics and display of user-defined groups only. It duplicates the function of *Show groups* on the *Group menu*.
- *Data req(uirements)* assembles data requirements for knowledge base processing. The *Save button* must have been pressed first or an error message is displayed. The *Data req button* also must be pressed before pressing the *Run button* if the analysis has never been run. After the initial run of an analysis, it is no longer necessary to press the *Data req button* before pressing the *Run button*. It duplicates the function of *Summarize data needs* on the *Analysis menu*.
- *Run* performs the analysis. It duplicates the function of *Run analysis* on the *Analysis menu*. See *Save* and *Data req(uirements)* on the *Assessment button bar* for important notes about how these three *buttons* interact.
- *Print* prints an ASCII script of the current instantiation of the knowledge base for the analysis. It duplicates the function of *Print* on the *Analysis menu*.
- *Help* displays the contents page of EMDS Help.
- *Exit* exits the EMDS Assessment system. If the current analysis has been edited since the last save, the Assessment system prompts, asking if it should be saved.

## Assessment Menu Bar

The function of commonly used *menu items* is replicated on the *Assessment button bar* (fig. 8). Most window objects also are illustrated in figure 8.

### *File menu—*

- *New analysis* loads an uninstantiated version of the currently loaded knowledge base.
- *Open analysis* loads an existing analysis (instantiated knowledge base) and initializes the knowledge base to its previously evaluated state.
- *Save* saves the current state of an analysis (instantiated knowledge base). *Save* must be selected before choosing *Summarize data needs* on the *Analysis menu* or an error message is displayed informing you to save the analysis first. A knowledge base can be saved after selecting a number of topics, then re-loaded later to continue selecting additional topics. Any change in knowledge base state resulting from additional topic selections or topic deletions requires resaving before getting data requirements. As a security measure, each set of modifications of this type requires a new analysis name. This assures that specific analyses cannot be overwritten inadvertently.
- *Save as* is similar to *Save*, above, except that a new analysis name is specified in a *file name dialog window*. The primary reason for using *Save as* is to create a copy of an analysis for further editing while keeping a copy of the current analysis.
- *Close* closes the analysis that is currently open. If the current analysis has been edited since the last save, the Assessment system prompts, asking if it should be saved.
- *Exit* exits the EMDS Assessment system. If the current analysis has been edited since the last save, the Assessment system prompts, asking if it should be saved.

### *Group menu—*

- *Make group* defines the current set of selected topics (networks in NetWeaver terminology) in the *Available topics window* as a custom group for future use in the present analysis. A *dialog window* opens, requesting a name for the group. On closing the *dialog window*, the group is added to the list of topics in the *Available topics window*.

- *Show group* toggles display of the topic hierarchy in the *Available topics window* between display of all topics and display of user-defined groups only. A check mark appears next to this *menu item* only when user-defined groups are displayed.

*Analysis menu—*

- *Undo include* undoes the action of *Include selected topic* (see below).
- *Show antecedents only* toggles display of the topic hierarchy. In the default state, the full hierarchy is displayed in the *Available topics window*. When this item is chosen (indicated by a check mark next to the *menu item*), only the topic currently selected in the *Available topics window* and its antecedent topics are displayed.
- *Include selected topics* places the set of topics that are currently selected in the *Available topics window* in the *Topics for analysis window*. Any topics included in the *Topics for analysis window* are now displayed as bold in the *Available topics window*.
- *Remove selected topic* removes topics that are currently selected in the *Topics for analysis window* from that window and removes bold face from these topics in the *Available topics window*.
- *Summarize data needs* assembles data requirements for knowledge base processing. The *Save button* on the *Assessment button bar* or *Save menu item* on the *File menu* of the *Assessment menu bar* must have been pressed first or an error message is displayed. *Summarize data needs* also must be selected before selecting *Run analysis* for the first time. After the initial run of a particular named analysis, *Summarize data needs* no longer needs to be chosen before choosing *Run analysis*.
- *Run analysis* performs the analysis. See *Save* on the *File menu* and *Summarize data needs* on the *Analysis menu* for important notes about how these three *menu items* interact.
- *Print* prints an ASCII script of the current instantiation of the knowledge base.

*Results menu—*

- *Map* displays a cascading menu (network truth value, missing data indicator, or data influence rank) to choose a type of map. For an explanation of map choices, see the section, “Performing an analysis,” “Viewing analysis results,” below. The *map dialog window* opens. Choose a topic or data item from the *list box* and press the *OK button* to generate a new ArcView theme for the selected information. After pressing the *OK button*, click anywhere on the ArcView window to bring this window to the foreground and view the resulting map.

- *Define ease of acquisition* opens the DAM subsystem, described later in this chapter.
- *Influence summary* opens the *influence dialog window*. Choose an item from the *list box* and press the *OK button* to generate a graph of the selected information in ArcView. For information about the types of graphs that can be generated, see the section, “Data Acquisition Subsystem,” “DAM results,” below. After pressing the *OK button*, click anywhere on the ArcView window to bring it to the foreground and view the resulting graph in ArcView.
- *Analysis tables* cascades to two additional choices: *Show* and *Hide*. Select *Show* to automatically display all input and output tables used or generated by NetWeaver. After pressing the *OK button*, click anywhere on the ArcView window to bring it to the foreground and view the set of tables in ArcView. While in ArcView, tables can be closed manually, one at a time, via the *control menu* on each *table window*. Alternatively, use *Analysis Tables-Hide* on the *Results menu* in the Assessment system to automatically close all NetWeaver input and output tables.

*What-if menu—*

**Scenario menu item—***Scenario* is a cascading *menu item* that contains the following *submenu items*:

- *New* opens a *filename dialog window* with an *edit line* to enter a name for a new scenario.
- *Open* opens a *filename dialog window* with a *list box* to choose the name of an existing scenario to load.
- *Save* saves the current state of the currently open scenario.
- *Save as* is similar to *Save*, but opens a *filename dialog window* with an *edit line* to enter a new name for the scenario.
- *Delete* opens a *filename dialog window* with a *list box* to choose the name of an existing scenario to delete from the analysis.

For additional discussion about use of these menu items, see the section, “Scenarios,” below.

**Edit records menu item—**This menu item opens the input database table (an ArcView table) for the currently loaded scenario. If landscape features have been highlighted in the ArcView EMDS *Assessment view*, then records corresponding to these features are highlighted in the input database table when the table is opened. See “Select features” in ArcView Help for details about this feature.

#### *Options menu—*

- *Set password* opens the *Password dialog window* to enter the EMDS password. The password must be entered before attempting to set truth values for analysis topics or data values for data links. A password is given initially only to the assessment team leader when EMDS is installed. The team leader then decides who should have access to the set value functionality.
- *Startup settings* opens the *Startup dialog window* to set default attributes for the Assessment system. *Edit lines* in the *dialog window* allow you to specify a default knowledge base to load or a specific analysis file (an instantiated knowledge base). A knowledge base can be specified without specifying a specific analysis. If an analysis file is not specified, then an uninstantiated copy of the knowledge base is loaded when the Assessment system opens. To open a specific analysis file at startup, its associated knowledge base also must be specified. *Radio buttons* in the *dialog window* allow a choice between text labels or graphic labels for the *Assessment button bar*.

#### *Help menu—*

*Contents* displays the contents page of Assessment system help.

*Search* displays the *search dialog window* of the help system.

*How to* displays key help topics that discuss how to use the various EMDS features and functions.

*Using help* explains use of help system features.

*About* displays information about EMDS and its designers.

### **Assessment Windows**

The Assessment system displays three *child windows* within the main Assessment window (fig. 8):

1. The *Available topics window* displays a NetWeaver knowledge base as a hierarchy of topics that can be browsed and selected for inclusion in an analysis. Use this window to select topics to be included in an analysis and to define custom sets of analysis topics to be added to the list of available topics in the knowledge base hierarchy. Details of both operations are explained in the section, "Selecting topics for analysis," below.
2. The *Details window* displays detailed information about the topic that is currently selected in the *Available topics window*.
3. The *Topics for analysis window* displays the list of topics that have been selected for inclusion in an analysis.



*Available topics window*—A NetWeaver knowledge base is a hierarchy of dependency networks (fig. 4). Each network corresponds to a topic of interest in the problem domain represented by the knowledge base. There is a one-to-one correspondence between networks in a NetWeaver knowledge base and topics that are available to be included in an analysis within the Assessment system. See the earlier section, “NetWeaver Knowledge Bases,” for a description of networks and data links.

All topics represented by dependency networks are available to be selected for inclusion in an analysis. The topic hierarchy (which is a transformation of the dependency network structure into hierarchical form) is displayed in the *Available topics window* (fig. 8).

Only the highest level topics are displayed initially in the *Available topics window* when a knowledge base is first loaded into the Assessment system. To expand the topic hierarchy beneath a specific topic, press the small *expand button* immediately to the left of the topic name. To collapse the topic hierarchy beneath a specific topic, press the *expand button* again. Methods for making multiple topic selections conform to Microsoft Windows conventions:

- **Shift-click** to select a contiguous set of topics.
- **Ctrl-click** to select multiple noncontiguous topics.

Once a set of topics has been selected in the *Available topics window*, it can be included in the topics for analysis or defined as a custom set of analysis topics for later reference in the same analysis or derivative analyses.

**Selecting topics for analysis**—Once a set of topics has been selected in the *Available topics window*, the set is added to the *Topics for analysis window* by pressing the *Include selected topic button* in the accessory button set or choosing *Include selected topic* from the *Assessment menu bar* (fig. 8).

Selected topics are displayed in the *Topics for analysis window* after the *Include selected topic button* has been pressed. The selected topics and all their antecedent topics (those on which they depend) are included in the analysis.

**Creating custom sets of analysis topics**—Once a set of topics has been selected in the *Available topics window*, this set can be defined as a custom group of topics for future reference in the same analysis by pressing the *Group button* on the *Assessment button bar* or choosing *Make group* from the *Groups menu*. In either case, a *dialog window* is displayed, requesting a name for the group. After the *dialog window* is closed, the new group is added to the list of topics displayed in the *Available topics window*.

To toggle display of the *Available topics window* between all topics and only custom groups, press the *Show button* on the *Assessment button bar* or choose *Show groups* from the *Groups menu* (fig. 8).

*Details window*—

**Documentation dropdown list box**—NetWeaver dependency networks and data links have several types of documentation attributes, such as comments, explanations, literature references, and assumptions. This information can be viewed, but not edited, in the *Details window* (fig. 8).

Use the *dropdown list box* at the top of the *Details window* to select a specific documentation attribute to view. Alternatively, press the *maximize button* on the *Details window* to expand the window to full size and view all details at once.

**Type field**—The *type field* identifies whether the topic that is currently selected in the *Available topics window* is a group, dependency network, or data link. See the earlier section, “NetWeaver Knowledge Bases,” for an explanation of these items.

**Weight field**—The *weight field* displays the weight associated with the topic or data link that is currently selected in the *Available topics window*. With rare exception, this usually will have a value of 1.0. Weights are not applicable to groups.

**Set value edit box**—The *Set value edit box* is empty unless a value is set by the user. It is used to set a **global value** for an analysis topic or data source that applies to all database records when an analysis is run. Normally, data values that are applied to NetWeaver data links are read from the appropriate IN.DBF file for the current analysis. Similarly, topics included in analysis normally are evaluated by evaluating their antecedent topics. Values for both data sources and analysis topics can be overridden, however, by the user after an initial analysis has been run. Changes to truth values of analysis topics and data values for data links cannot be made in the initial analysis because it generates the tables on which such edits are performed.

Once an initial analysis has been run, values for either topics or data links may be set directly in the *Set value edit box* or via the *Set value dropdown list box* (see the next subsection). To set a value for an analysis topic or a data source via the *Set value edit box* (fig. 8):

1. Highlight the appropriate item in the *Available topics window* whose value is to be set by clicking on it.
2. Click inside the *Set value edit box* to get an edit cursor.
3. Type in the value to which the item should be set.
4. Click anywhere within the Assessment window.

See the section, “Setting Values for Topics and Data,” below for additional information about overriding data sources and evaluation of analysis topics, and documenting changes to a knowledge base or its data.

The Assessment system performs some basic range and type checking when values are set *via* the *Set value edit box*:

- Truth values of topics either must be in the inclusive range, -1 to 1, or be one of the predefined constants, True (1), False (-1), or Undetermined (0).
- The value for a data source that has a list of choices associated with it can only be one of the choices. It is best, however, to use the *Set value dropdown list box* in this situation because the latter data entry object displays the choice list.
- The value for a data source can be any real number if the data link does not have a list of choices associated with it.

**Set value dropdown list box**—The *Set value dropdown list box* is displayed to the right of the *Set value box* and is used to set a global value for an analysis topic or data source that is applied to all database records when an analysis is run.

Values may be set directly in the *Set value edit box* (see the previous subsection) or *via* the *Set value dropdown list box*. To set a value for an analysis topic or for a data source *via* the *Set value dropdown list box*:

1. Highlight the appropriate item in the *Available topics window* whose value is to be set by clicking on it.
2. Click on the *down arrow* on the right side of the *list box* to open it and display the set of available choices.
3. Click on one of the choices to set the value of analysis topic or data link.

Choices for analysis topics are:

- **True** sets the value of the topic to true.
- **False** sets the value of the topic to false.
- **Undetermined** forces the value of the topic to **remain undetermined** (the analysis is conducted as if there were no data to evaluate the topic).
- **Required** forces any topic that depends on the selected topic to be treated as unevaluated if the required topic is not fully evaluated.
- **Ignore** effectively removes the topic from the knowledge base (the knowledge base is evaluated as if the topic were not in the knowledge base).

- **Reset** sets the topic to its default condition before running an analysis, which is the undetermined state. The **Reset** option is different from the **Undetermined** option, above, because a topic that is reset **will be** evaluated in an analysis, but a topic that is **set to** undetermined is **forced to remain undetermined**.

Choices for data links are:

- A list of data value choices if a choice list was defined for the data link in NetWeaver.
- **Empty** forces the datum for the data link to be treated as missing even if it exists in IN.DBF (the data link is forced to remain unevaluated).
- **Ignore** effectively removes the data link from the knowledge base (the knowledge base is evaluated as if the data link were not in the knowledge base).
- **Required** forces any analysis topic that depends on the selected data link to be treated as unevaluated if the datum for the data link is missing in IN.DBF.
- **Reset** sets the data link to its default condition before running an analysis, which is the undetermined state. The **Reset** option is different from the **Empty** option, above, because a data link that is reset **will be** evaluated in an analysis but a data link that is **set to** empty is **forced to remain undetermined**.

**Annotation button**—Press the *Annotation button* to open an *edit window* in which notes may be added concerning the topic that is currently selected in the *Available topics window*. Notes are specific to the current analysis or its derivatives; that is, if notes are added about a topic and the analysis is saved under a new name with the *Save analysis button* on the *Assessment button bar*, the notes are carried into the new analysis.

The annotation window also is used to document reasons for setting data and analysis topic values (see the section, “Setting Values for Topics and Data,” below).

*Topics for analysis window*—This window displays the set of analysis topics that have been selected for inclusion in an analysis. The *Accessory button set* (see the following section), located between the *Available topics window* and the *Topics for analysis window*, is used to add and remove topics from the window (fig. 8). Alternatively, choose *Include selected topic* and *Remove selected topic* from the *Analysis menu* to add and remove topics, respectively.

Although not displayed in the *Topics for analysis window*, any topics that are antecedent to an included topic (that is, topics on which the included topic depends) are automatically included in an analysis.

## Accessory Button Set

The *Accessory button set* used in the Assessment system is arranged vertically and located between the *Available topics window* and the *Topics for analysis window* (fig. 8).

- The *Show/hide hierarchy button* toggles display of the topic hierarchy in the *Available topics window*. In the default show state, the full hierarchy is displayed. Press this *button* to hide all the hierarchy except the topic currently selected in the *Available topics window*. This *button* duplicates the function of *Show antecedents only* on the *Analysis menu*.
- *Include selected topic button* places the set of topics currently selected in the *Available topics window* in the *Topics for analysis window*. Any topics included in the latter window are now displayed as bold in the *Available topics window*. This *button* duplicates the function of *Include selected topic* on the *Analysis menu*.
- *Remove selected topic* removes topics that are currently selected in the *Topics for analysis window*. This *button* duplicates the function of *Remove selected topic* on the *Analysis menu*.

## Setting Values for Topics and Data

Setting values via the *Set value edit line* or *Set value dropdown list box* in the *Details window* overrides normal knowledge base processing by inserting values for analysis topics and data links that apply globally to all records processed in an analysis. The setting values feature can be used in both the standard analysis and the scenario mode of analysis. Setting values is not allowed, however, until an initial analysis has been run.

*Documentation*—There often are compelling reasons to use the set value feature, but setting values can profoundly influence an analysis and should always be documented carefully by an assessment team. Any time that the set value feature is implemented by the user, the Assessment system displays a *dialog window* with a message prompting the user to document the set value action. After pressing the *OK button* to close the *dialog window*, the Assessment system displays an *edit window* in which to enter relevant documentation. To refer to documentation that has been entered concerning values that have been set for a particular analysis topic or data link:

1. Highlight the relevant item in the *Available topics window*.
2. Press the *Annotation button* in the *Details window*.

*Justification for setting values*—There are three general cases in which it may be desirable and justifiable to set values for analysis topics and data links.

1. Actual data are lacking, but there is sufficient circumstantial knowledge about the missing information to provide reasonable data estimates.
2. One or more individuals may have direct knowledge about the truth value of a proposition being tested by an analysis topic, in which case they may be willing to say that the proposition is generally true or false.
3. Setting values for analysis topics and data links is perfectly justifiable in what-if analysis, if one is looking only at the effects of hypothetical conditions.

### **Performing an Analysis**

The basic steps to performing an analysis within the Assessment system are:

1. Load the knowledge base into Analysis if the Assessment system does not automatically load the desired knowledge base. If the Assessment system automatically loads the correct knowledge base, the loaded knowledge base either may be instantiated (that is, represents an existing analysis) or uninstantiated, depending on options set from the *Options menu* (see *Options menu* in the earlier section, “Assessment Menu Bar”).
2. Select topics to include in an analysis. If an analysis (instantiated knowledge base) was loaded at startup of the Assessment system, there may be no need to select topics. If the topics included for analysis are not changed upon loading an existing analysis, steps 4 and 5, below, should be skipped.
3. Optionally, create custom sets of analysis topics.
4. Save the current state of the analysis under a new name. Saving is required whenever the set of topics included in an analysis changes. It is not necessary to save the analysis after an initial analysis has been run or upon loading an existing analysis if subsequent changes are made only *via* the set value function because the state of the analysis is automatically saved when the *Run button* is pressed.
5. Get data requirements to run an analysis if the analysis has never been run. After the initial run of an analysis, there is no need to get data requirements.
6. Run an analysis. The sequence of operations invoked by the run command are summarized in the earlier section, “NetWeaver Knowledge Bases,” “Knowledge Base Processing.”
7. Display maps of truth values associated with analysis topics and related information. See below, “Viewing analysis results,” “Maps,” for detailed steps.

*Loading a knowledge base*—A knowledge base can be loaded at any time from the Assessment window.

1. Choose *Load knowledge base* on the *File menu* to load a copy of an uninstantiated knowledge base into the Assessment system and begin a new analysis.
2. Choose the knowledge base to load from the *file name list box* in the *Load knowledge base dialog window*.
3. Press the *OK button*.

By default, the *file name list box* displays knowledge bases contained in the \NWKB folder under your specific EMDS-ArcView project folder (for example, \MY-EMDS\NWKB). If the knowledge base to be loaded is in a different folder, then use the *directory list box* in the *dialog window* to navigate to the appropriate folder at step 2. An actual assessment may include two or more EMDS-ArcView projects, so it may be helpful for overall project organization to keep your team's collection of knowledge bases in the central \EMDS\NWKB folder (where NetWeaver stores them by default), and copy them to specific project folders where they are actually used. Aside from organization, this approach to maintaining knowledge bases has the added benefit of maintaining readily available backups of your knowledge bases.

The *Options menu* on the *Assessment menu bar* includes startup options to automatically load a specific knowledge base when the Assessment system starts.

*Starting a new analysis*—A new analysis can be started at any time from the Assessment window. Press the *New button* on the *Assessment button bar* or choose *New analysis* on the *File menu* to reload an uninstantiated copy of the current knowledge base into the Assessment system.

Loading an existing analysis—

1. Choose *Open analysis* on the *File menu* or press the *Open button* on the *menu bar* to load an existing analysis (instantiated knowledge base) into the Assessment system.
2. Choose the analysis to load from the *file name list box* in the *File name dialog window*.
3. Press the *OK button*.

*Saving the currently loaded analysis*—An analysis can be saved at any time by choosing *Save analysis* on the *File menu* or by pressing the *Save button* on the *Assessment button bar*.

If an analysis is already loaded in the Assessment system when you start a new analysis or load an existing analysis, a *dialog window* will prompt to save the analysis that is currently loaded before loading a new one. There are three options:

1. Press the *Cancel button* to abort the operation. The currently loaded analysis remains in the Assessment system to continue editing.
2. Press the *Save button* to save the currently loaded analysis. If the analysis has not been saved yet or if changes have been made since the last save, then a *dialog window* will prompt for the analysis name. After saving the loaded analysis, a *file name list box* is displayed to select a new analysis to load.
3. Press *Don't save*. The currently loaded analysis is discarded and a *File name list box* is displayed as in option 2, above, to select the name of the analysis to load.

*Saving an existing analysis under a new name*—At times, you may have an analysis, named A, whose state you want to preserve for use in future analysis runs, but you also want to develop a new analysis or scenario, named B, that is a further modification of analysis A. Rather than creating a new analysis and reconstructing the edits applied to analysis A, analysis A can be saved as analysis B or scenario B. To rename the currently loaded analysis to a new analysis name:

1. Choose *Save as* on the *File menu* of the *Assessment menu bar*.
2. Enter the new name on the *edit line* in the *File name dialog window*.
3. Press the *OK button*.

The currently loaded analysis also can be the basis for a new scenario. Similar to renaming an existing analysis to a new analysis name, an existing analysis also can be saved as a scenario. To rename an existing analysis so that its state becomes the basis for a scenario:

1. With an analysis loaded in the Assessment system, choose *Save* on the *Scenario submenu* of the *What-if menu* on the *Assessment menu bar*.
2. Enter a new scenario name in the *edit line* of the *Save dialog window*.
3. Press the *OK button* to save the analysis as a scenario.

*Running an analysis for the first time*—Six steps are required to run an analysis in the Assessment system for the first time:

1. Start a new analysis by pressing the *New analysis button* on the *Assessment button bar*.
2. Select topics from the *Available topics window* to be included in the analysis (see above section, “Selecting topics for analysis,” for details).

3. Add the selected topics to the *Topics for analysis window* by pressing the *Include selected topic button* in the *Accessory button set*.
4. Save the current state of the analysis by pressing the *Save button* on the *Assessment button bar*.
5. Perform the initial data requirements analysis by pressing the *Data req(uiirements) button* on the *Assessment button bar*.
6. Press the *Run button* on the *Assessment button bar*. During the initial analysis run, the Data Engine in ArcView assembles the database for the assessment area by querying the source databases specified in the Data Catalog and clipping the data to the boundary of the assessment area.

*Running subsequent analyses*—After the initial analysis run has been completed as described in the previous section, the process for subsequent runs is much more abbreviated:

1. Set data values for data links and truth values for analysis topics as described in the earlier sections, “Set value edit box” and “Set value dropdown list box.”
2. Press the *Run button* on the *Assessment button bar*.

Although the *Save button* on the *Assessment button bar* can be pressed before pressing the *Run button*, the Assessment system automatically saves the current state of an analysis as the first step of the run process.

Data requirements for an analysis are assessed only when the analysis is run for the first time. An important related issue about subsequent analysis runs is that the IN.DBF file is assembled only during the initial run of an analysis (see the previous section, “Running an analysis for the first time”). Consequently, in the current version of EMDS, the initial analysis run freezes the state of the input data. If the source databases for an analysis are updated after the initial analysis run, it is necessary to perform a new analysis to update the state of IN.DBF.

*Viewing analysis results*—

**Maps**—The EMDS Assessment system can display a variety of maps in ArcView after an analysis has been run:

1. Choose *Maps* on the *Results menu*.
2. Choose the type of map to display from the *cascading submenu* (analysis topic truth value, missing data indicator, or data influence rank). For an explanation of map choices, see below.

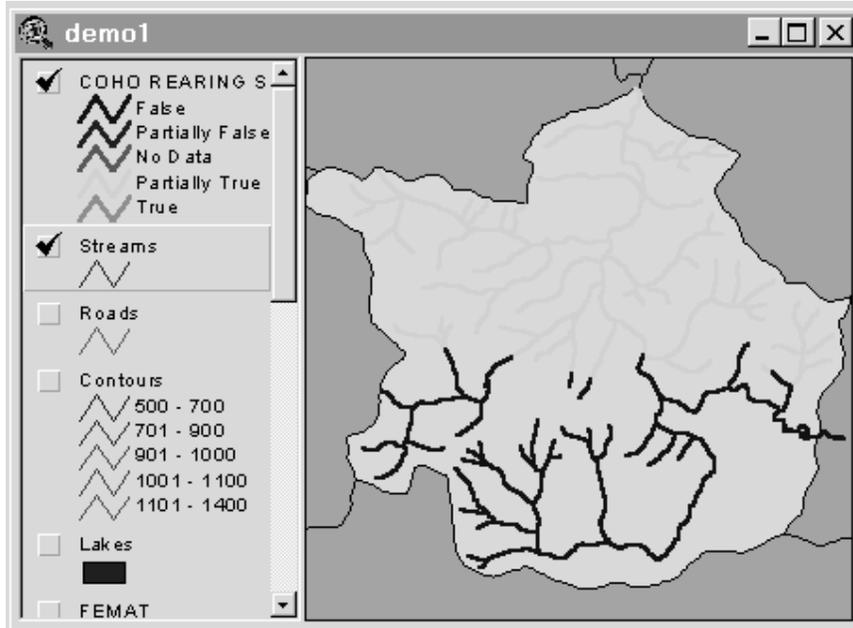


Figure 9—Example of a map output, displayed in the *Assessment view*, from the Assessment system displaying truth values for a topic related to salmon habitat.

3. In the *Map dialog window*, choose a topic from the list box and press the *OK button* to generate a map of the selected information in ArcView.
4. After pressing the *OK button*, the map can be viewed in ArcView by clicking anywhere within the ArcView application window to raise the window to the foreground.

*Truth value maps* displays the list of topics that have been included in the analysis. Select an item from the list to display a map of truth values for the topic in ArcView (fig. 9). A check box provides the option to create a new (additional map) or replace the previous one (if any) in the table of contents of the *Assessment view*.

*No data values* generates a map indicating landscape features in the associated ArcView theme for which the selected data link has no data (fig. 10). On selecting *No data values*, a dialog window displays the list of data links topics associated with topics that have been included in the analysis. A check box provides the option to create a new (additional map) or replace the previous one (if any) in the *Assessment view* table of contents.

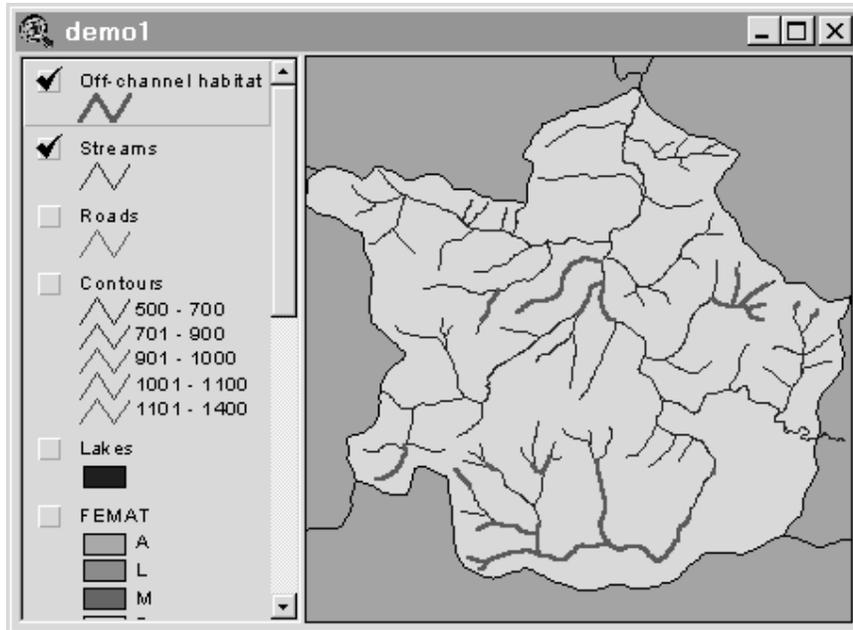


Figure 10—Map output from the Assessment system, displayed in the *Assessment view*, indicating locations of features for which a particular data source is missing.

*Rank values* generates a map indicating influence rank by landscape feature of the selected data link in the associated ArcView theme. A dialog window displays the list of data link topics associated with topics that have been included in the analysis. A check box provides the option to create a new (additional map) or replace the previous one (if any) in the *Assessment view* table of contents.

### Graphs—

1. Choose *Influence summary* on the *Results menu* to open the *influence dialog window*.
2. Choose an item from the *list box* and press the *OK button* to generate a graph of the selected information in ArcView. For information about the types of graphs that can be generated, see the section, “DAM results,” below.
3. After pressing the *OK button*, the graph can be viewed in ArcView, by clicking anywhere within the ArcView application window to raise the window to the foreground.

## Tables—

1. Choose *Analysis tables* on the *Results menu*.
2. This *menu item* cascades to two additional choices: *Show and Hide*.
3. Choose the *Show submenu item* to display all input and output tables used or generated by NetWeaver.
4. After pressing the *OK button*, the set of tables can be viewed in ArcView by clicking anywhere within the ArcView application window to raise the window to the foreground.

While in ArcView, the tables can be closed manually, one at a time, via the *control menu* on each table window. Alternatively, use *Analysis Tables-Hide* on the *Results menu* to automatically close all NetWeaver input and output tables.

## Hotlink Browser

This subsystem of the Assessment system displays the evaluated state of a NetWeaver knowledge base in detail for a specific landscape feature that has been selected in the *Assessment view* after an analysis has been run from the Assessment system.

The *Hotlink Browser window* displays two *child windows* in its default configuration. The upper *Outline window* displays an outline view of the knowledge base similar to the display in the *Available topics window* of the Assessment system interface. The logic structure of networks highlighted in the *Outline window* is displayed in the lower *Network window*.

### Opening the Hotlink Browser

In ArcView, open the Hotlink Browser to view and navigate the structure of the evaluated knowledge base for the selected feature (fig. 11). The selected feature is highlighted in yellow in the *Assessment view* in ArcView. To open the Hotlink Browser:

1. Display a truth value map for one of the topics included in an analysis (see the section, “Performing an analysis,” “Viewing results of an analysis,” above).
2. In the *Assessment view*, click on the theme in the *table of contents* to activate the theme. When activated, the theme is surrounded by a raised box in the *table of contents*.
3. On the ArcView *tool bar*, click on the *hotlink tool* to select it.
4. With the *hotlink tool* active, click on one of the landscape features displayed in the theme to open the Hotlink Browser.

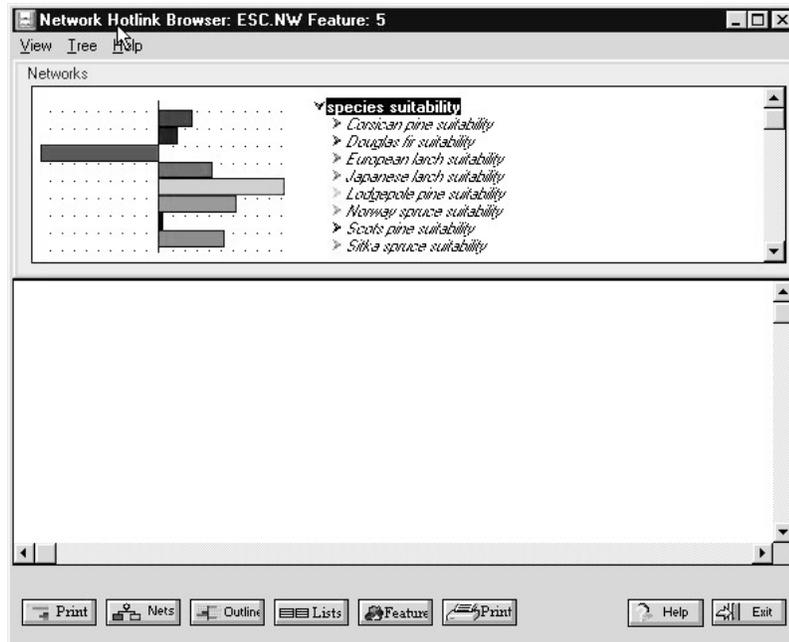


Figure 11—The Hotlink Browser displays the evaluated state of a knowledge base for landscape features selected from a truth value map output to the *Assessment* view by the Assessment system.

### Hotlink Browser Outline Window

The knowledge base outline is displayed in the upper *Outline window* of the *Hotlink Browser window* (fig. 11). By default, the *Outline window* is displayed when the Hotlink Browser is opened. To hide the *Outline window* and expand the *Network window* to the full display area of the Hotlink Browser, press the *Nets* button at the bottom of the application window. To restore the *Outline window*, press the *All* button.

Truth value bars are displayed to the left of the knowledge base outline. The outline begins with the highest level knowledge base groups or networks that were selected for inclusion in an analysis. The outline displays only truth values for networks.

Use the up and down arrow keys to scroll through the outline or use the mouse. Networks highlighted in the *Outline window* are displayed in the lower *Network window* of the *Hotlink Browser window*.

The right arrow key expands the knowledge base outline under the highlighted group or network. The left arrow key collapses the knowledge base outline under the highlighted group or network.

## Hotlink Browser Network Window

The *Network window* of the Hotlink Browser displays the network structure of the network currently selected in the *Outline window* (fig. 11). By default, the *Network window* is displayed when the Hotlink Browser is opened. To hide the *Network window* and expand the *Outline window* to the full display area of the Hotlink Browser, press the *Outline button* at the bottom of the application window. To restore the *Network window*, press the *All button*.

As in the NetWeaver knowledge base development environment, truth value states of evaluated networks and data links are displayed with color coding in the *Network window*, with brighter greens indicating increasingly positive truth values and brighter reds indicating increasingly negative truth values. Actual truth values or data values for network objects displayed in the *Network window* are displayed in the status bar at the bottom of the Hotlink Browser application window.

## Hotlink Browser Buttons

The *Hotlink Browser buttons* provide control over the appearance of the *Hotlink Browser window* and allow selection of new features to display within the *Hotlink Browser window* (fig. 11).

**Expand** expands and collapses the knowledge base outline for the group or network currently highlighted in the outline. This function is duplicated by the left and right arrow keys.

**Nets** hides the *Outline window* and expands *Network window* to the full area of the *Hotlink Browser window*. The *Nets button* is replaced by the *All button*.

**Outline** hides the *Network window* and expands *Outline window* to the full area of the *Hotlink Browser window*. The *Outline button* is replaced by the *All button*.

**All** replaces the *Nets button* or the *Outline button* when either of these buttons is pressed. Press the *All button* to return display of the *Hotlink Browser window* to its default state in which both the *Network window* and the *Outline window* are displayed.

**Lists** toggles on and off the display of two additional list boxes.

**Features** displays a dialog window with which to choose a new feature from the *Assessment view* to be displayed in the *Hotlink Browser window*. The evaluated state of the new feature is displayed in the *Hotlink Browser window* and the newly selected feature is now highlighted in yellow in the *Assessment view* in ArcView.

**Help** displays the cue card for the *Hotlink Browser window*.

**Exit** closes the *Hotlink Browser window*.

The *Menu bar* in the *Hotlink Browser window* duplicates all functions of the *Hotlink Browser buttons*. The *View menu* also has a *Network scale menu item* that controls sizing of the display within the *Network window*.

## Data Acquisition Manager

Information about the influence of missing data can be as important to an assessment as information that can be derived from the data that you **do** have. There are two basic questions about missing data that determine its priority for collection:

1. Which missing data should be acquired to improve completeness of an assessment, considering the influence of the missing information?
2. How easy is it to obtain the missing data?

The DAM is a subsystem of the EMDS Assessment system (fig. 1). When the Assessment system runs the NetWeaver engine on a knowledge base, the engine, in addition to performing an analysis of ecosystem states and processes, also generates information about the influence of missing data so the NetWeaver engine automatically answers the first question in the course of processing a knowledge base. The DAM determines the priority of missing data by synthesizing a priority score from each data source's influence score and a measure of its "ease of acquisition."

The DAM analysis is initiated by choosing *Define ease of acquisition* from the *Results menu* on the *Assessment menu bar*.

The basic steps in the DAM process are:

1. Allocate relative importance among the two decision criteria, data influence and ease of acquisition.
2. Score each missing data type for ease to acquire missing data.
3. The DAM then computes a priority for acquisition for each data type that has missing data.

### DAM Process

The DAM uses the two criteria, data influence and ease of acquiring the missing data, to evaluate the priority of missing information. The first window displayed by the DAM asks for a judgment about the relative importance of data influence versus ease of acquisition (fig. 12). By default, the two criteria are equally weighted.

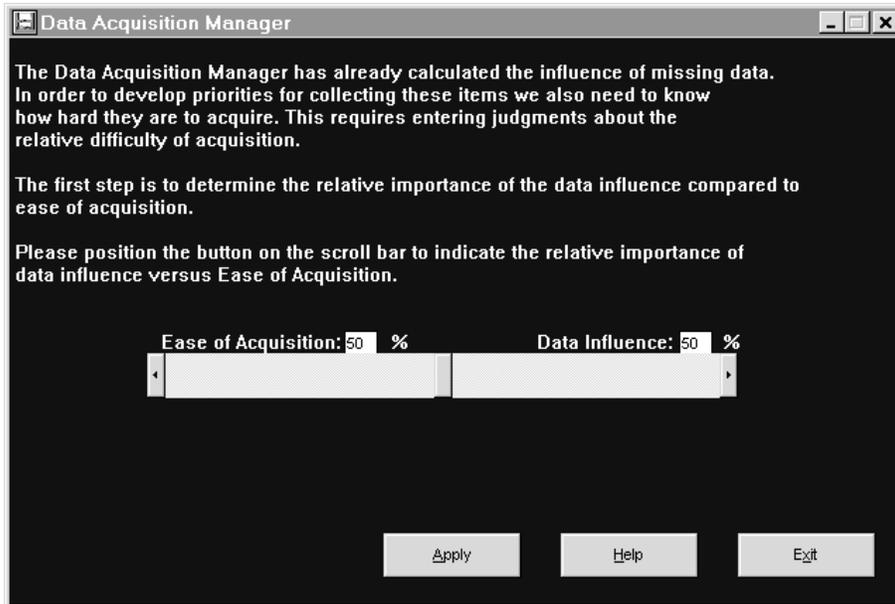


Figure 12—First step of the DAM process is allocating relative importance among the two criteria, data influence and ease of acquiring missing data.

*Getting started—*

1. In the first DAM window, drag the *button* on the *slide bar* to allocate importance among the two decision criteria, data influence and ease of acquisition (fig. 12).
2. Press the *Apply button*.
3. The next display explains the process and asks you to choose one of two methods for assigning ease of acquisition. You can either directly rank ease of acquisition (which the DAM will recommend if there are less than 15 data sources with missing data) or sort data sources into general categories ranging from very easy to very hard. Press either the *Categorize button* or the *Don't categorize button*.

See the section, “Sorting data types,” or the section, “Directly ranking ease,” for details about the next step, depending on the choice in step 3. At step 3, the *Back button* also may be pressed to return to the previous DAM display if it is decided that the allocation of the importance between the two decision criteria is not correct.

*Sorting data types—*When there are 15 or more data sources to be ranked for ease of acquisition, it may be helpful to first sort the full set into general categories. If this option has been selected, all data sources initially are assigned to the very easy category (fig. 13).

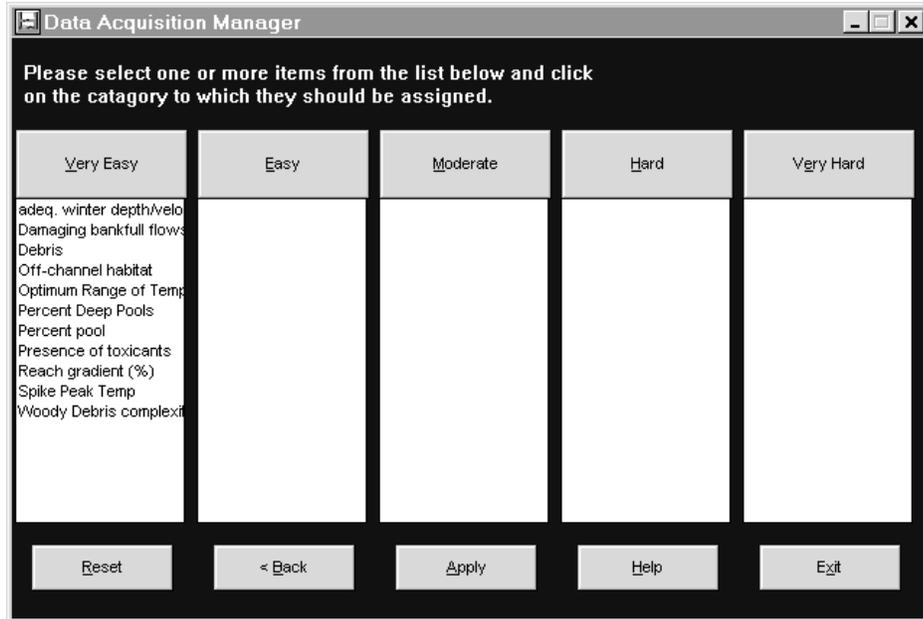


Figure 13—Sorting missing data sources into categories for ease of acquisition.

1. Select one or more data sources from the very easy category.
2. Click on one of the other headings to reassign the selected data sources to that category. Repeat this step as many times as necessary to sort the data sources.
3. When the sorting is satisfactory, press the *Apply button* to move to the next display in which category scores may be fine tuned. This is the same display used to directly rank ease of acquisition, described in the next section.

Methods for making multiple data source selections conform to Microsoft Windows conventions: **Shift-click** to select a contiguous set of topics and **Ctrl-click** to select multiple noncontiguous topics. Multiple selections can be made among two or more category *list boxes* at one time.

*Directly ranking ease*—The window displayed for direct ranking of ease also is used to refine scores that were first assigned by sorting data sources into general categories, as explained in the previous section (fig. 14).

If this display is entered by having chosen direct ranking, all data types are initially assigned a score of 1.0, meaning that ease of acquisition is extremely easy (trivial). If this display is entered by having first performed a sort into general categories, the midrange score of the appropriate assigned category will be assigned to each data source initially.

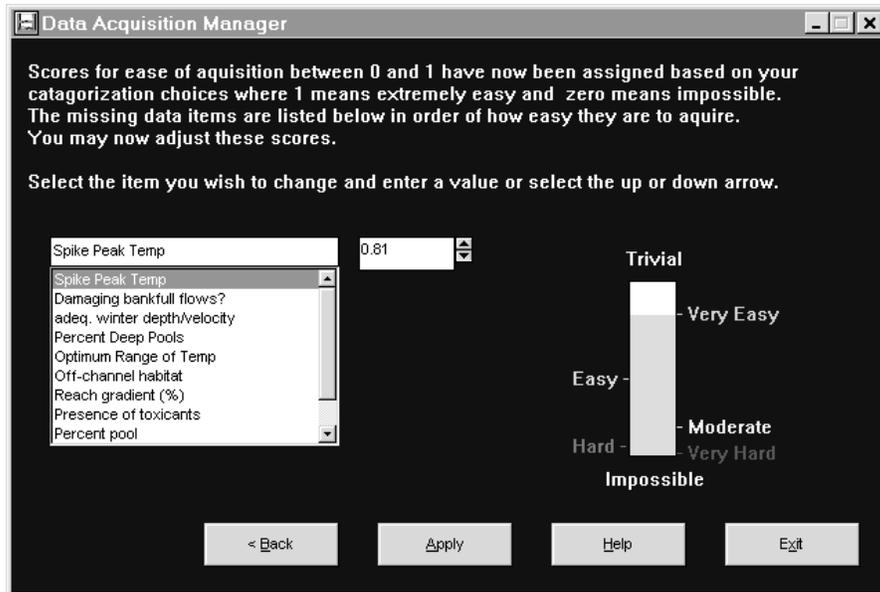


Figure 14—Directly ranking ease of acquisition for missing data sources or refining scores from an initial categorization.

In either case, select an individual data source from the *list box* on the left side of the display, and adjust its score as desired. Adjustments can be made either by typing a value directly into the *edit box* on the upper right side of the *list box* or by clicking on the *up/down spin buttons* next to the *edit box*.

A labeled vertical bar on the right side of the display provides a verbal interpretation of the score assigned to the currently selected data source in the *list box*. The bar dynamically adjusts as scores are modified.

After scores are assigned to each data type for ease of acquisition, press the *Apply button* to complete the scoring process. The DAM then synthesizes a priority for data acquisition as a weighted average of the influence score and the ease of acquisition score by using the relative weighting set on the *slide bar*.

### DAM Results

Once the process has been completed for setting acquisition priorities for data sources with missing values, several graphs can be selected for display in ArcView:

1. Choose *Influence Summary* from the *Results menu* on the *Assessment menu bar*.
2. Next, choose *Graph* from the *submenu*.

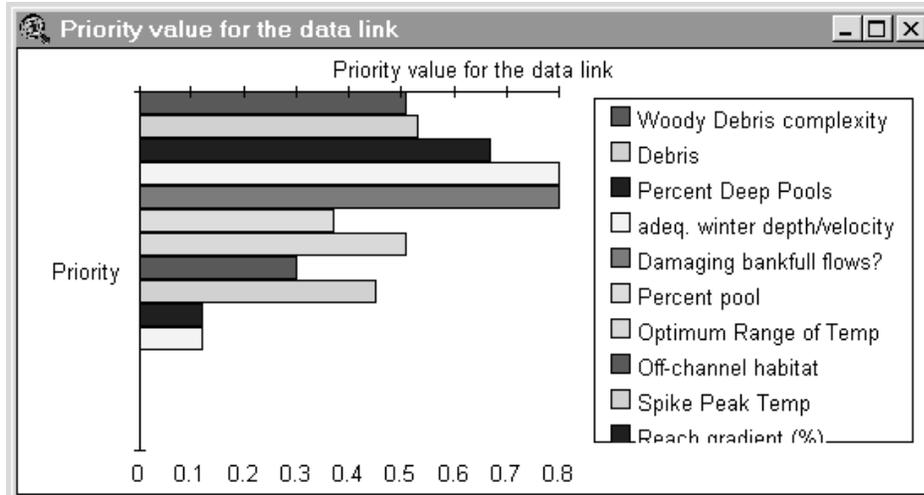


Figure 15—Calculated priorities for missing data sources in an example DAM analysis.

3. A dialog window displays the following choices:
  - Priority value for data links (synthesis of ease of acquisition and data influence)
  - Ease of acquisition (supplied by the user in the DAM)
  - Influence (computed by the NetWeaver knowledge base engine)
  - Number of rows (records) with influence (for each data source)
  - Percent of rows with influence (for each data source)
  - Number of no data values (for each data source)
  - Percent of no data values (for each data source)
4. Make a selection from the list of *menu items*.
5. Press the *OK button* to display the graph in ArcView.
6. Click anywhere within the ArcView application window to raise the window to the foreground and view the graph (fig. 15).

A data type may have missing data (number of no data values is positive) but not have any influence on improving the completeness of the assessment. The reason for this is that the missing data are not relevant, given the availability of other data.

## Scenarios

The purpose of the Scenario subsystem is to explore alternative future conditions (“what if” scenarios) and their implications for ecosystem states and processes. Within Scenario, you can modify the input data that is evaluated by a knowledge base or modify the structure of the knowledge base itself, in effect posing questions such as, What if the data looked like this? or What if this topic in the knowledge base is ignored?

The original input database for an analysis is not modified when a scenario is created. Instead, when a what-if analysis is conducted in the Scenario subsystem, the analysis is performed on a copy of the original input database. The original input database for an analysis is not assembled until the run command has been executed for the first time in the Assessment system, so scenarios cannot be run until an actual analysis first has been run.

### Creating a New Scenario

1. Choose *New* on the *Scenario submenu* of the *What-if menu* on the *Assessment menu bar*.
2. Enter a new scenario name on the *edit line* of the *New scenario dialog window*.
3. Press the *OK button* to create the new scenario.

After the *OK button* is pressed, Scenario creates copies of the base analysis tables, IN0.DBF and FLAG0.DBF, for the new scenario. The input tables for the first scenario created are designated IN2.DBF and FLAG2.DBF (the initial analysis tables are designated IN1.DBF and FLAG1.DBF; see the section, “Running an analysis,” above). Tables for subsequent scenarios are numbered sequentially thereafter.

### Setting Values for Topics and Data

*Global data editing and structural changes to the knowledge base*—Use the *Set value edit box* or the *Set value dropdown list box* in the *Details window* to set a global value for an analysis topic or data source that applies to all database records when a scenario is run. See descriptions of *Details windows* components in the section, “Assessment interface,” “Analysis windows” for methods of applying changes to data and knowledge bases to create a scenario. Also see the earlier section, “Setting Values for Topics and Data,” for a discussion about documenting changes and justifications for changes.

#### *Editing individual input database records—*

1. Choose *Edit records* on the *What-if menu* to design an alternative scenario for the current analysis based on changes to specific database records.
2. ArcView displays the input database table and the flag table for the currently selected scenario.
3. Modify records in the input database for the selected scenario (for help editing database records, see the topic “Editing records” in ArcView Help).

#### **Saving an Existing Scenario**

Scenarios are automatically saved whenever a scenario is run (see “Running a Scenario,” below). If you exit the Assessment system and the current analysis is a scenario, the Assessment system asks if the current scenario should be saved if any editing has been done on the scenario since it was last saved. To save the current state of an existing scenario at any other time, choose *Save* on the *Scenario submenu* of the *What-if menu*.

#### **Saving a Scenario Under a New Name**

At times, you may have a scenario (“scenario A”) whose state you want to preserve, but you also want to develop a new scenario (“scenario B”) that is a further modification of the currently loaded scenario. The methods discussed above for creating a new scenario always create a new scenario by copying the base analysis files, IN0.DBF and FLAG0.DBF. Rather than creating a new scenario and reconstructing the edits applied to “scenario A,” use the *Save as* function to rename “scenario A” as “scenario B.”

1. With a scenario loaded in the Assessment system, choose *Save as* on the *Scenario submenu* of the *What-if menu* on the *Assessment menu bar*.
2. Enter a new scenario name in the *edit line* of the *Save as dialog window*.
3. Press the *OK button* to save the scenario under the new name.

After the *OK button* is pressed, Scenario copies IN(X).DBF and FLAG(X).DBF for the current scenario to IN(N+1).DBF and FLAG(N+1).DBF for the new scenario, where N indicates the last-assigned scenario sequence number. For example, if the input tables for “scenario A” are IN2.DBF and FLAG2.DBF, and there are no other scenarios for the current analysis, the tables for “scenario B” will be IN3.DBF and FLAG3.DBF.



### **Deleting a Scenario**

1. Choose *Delete* on the *Scenario submenu* of the *What-if menu* on the *Assessment menu bar*.
2. Click on a scenario name in the list box of the *delete dialog window* to highlight the name of the scenario to be deleted.
3. Press the *OK button* to delete the scenario.

### **Running a Scenario**

To run a what-if scenario analysis after modifying the input database for the scenario or the knowledge base structure, press the *Run button* on the *Assessment button bar*. If any edits have been made to the analysis *via* set value operations, the scenario is automatically saved before running the scenario.

### **Returning to Normal Analysis Mode**

To return to the standard Assessment system mode of operation, load an existing analysis or start a new analysis.



# Acknowledgments

EMDS is a unique synthesis of several different state-of-the-art software technologies. Each of the companies involved is an innovator in its respective field. But this fact by itself would not have been sufficient to produce the system. The current, evolving system is the result of a lot of hard work, expertise, imagination, coordination, and cooperation of many people and organizations. It has been an honor and a privilege to work with such a group.

## Cooperators

Cooperators who participated in systems analysis and design to support development of EMDS version 1.0 are Michael Saunders and Michael Foster (Pennsylvania State University, University Park, PA); Richard Olson (Agricultural Research Service, Crop Science Research Laboratory, Mississippi State, MS); and Donald Latham (USDA Forest Service, Intermountain Research Station, Missoula, MT).

## Contractors

The Environmental Systems Research Institute (ESRI) is the primary contractor in charge of system implementation. The ESRI ArcView application is the primary interface to the EMDS system. Primary roles of ESRI are overall management of system implementation, and development of extensions to ArcView to provide project and data management functions specific to EMDS. The senior programmer in charge of EMDS development is Scott Murray (Environmental Systems Research Institute, Redlands, CA).

Knowledge Garden, Inc., is a knowledge-based systems development company. Its primary business is development, distribution, and support for the KnowledgePro system, but it is subcontracting to ESRI on EMDS system development. The primary role of Knowledge Garden in system development has been to develop runtime and development interfaces to the NetWeaver engine (licensed by Knowledge Garden from Pennsylvania State University). John Slade is president of Knowledge Garden and the company's senior programmer in charge of EMDS development (Knowledge Garden, Inc., West Palm Beach, FL).

Bruce Miller (Rules of Thumb, Inc., North East, PA), working with Michael Saunders, was the senior programmer in charge of the original development of NetWeaver. As an independent contractor on the EMDS project, he developed the Microsoft Windows version of the NetWeaver engine, and worked closely with Knowledge Garden, Inc., and ESRI on interface issues between system components.

### **Literature Citations**

**Anonymous. 1994.** Fuzzy logic applied to catchment modelling. *Water & Wastewater International*. 9: 40-43.

**Anonymous. 1996.** Using ArcView GIS. Redlands, CA: ESRI Inc.

**Anonymous. 1997.** Using Spatial Analyst. Redlands, CA: ESRI Inc.

**Baum, Bryan A.; Tovinkere, Vasanth; Titlow, Jay; Welch, Ronald M. 1997.** Automated cloud classification of global AVHRR data using a fuzzy logic approach. *Journal of Applied Meteorology*. 6: 1519-1523.

**Blonda, P.; Bennardo, A.; Satalino, G.; Pasquariello, G. 1996.** Fuzzy logic and neural techniques integration: an application to remotely sensed data. *Pattern Recognition Letters*. 17: 1343-1349.

**Booch, G. 1994.** Object oriented analysis and design with applications. New York: Benjamin/Cummings. 589 p.

**Davis, J.R.; Clark, J.L. 1989.** A selective bibliography of expert systems in natural resource management. *AI Applications*. 3: 1-18.

**Durkin, J. 1993.** Expert systems: catalog of applications. Akron, OH: Intelligent Computer Systems, Inc. 49 p.

**Gall, J. 1986.** Systematics: how systems really work and how they fail. Ann Arbor, MI: The General Systematics Press. 285 p.

- Hahn, A.; Pfeiffenberger, P.; Wirsam, B.; Leitzmann, C. 1995.** Evaluation and optimization of nutrient supply by fuzzy logic. *Ernährungs-Umschau*. 42: 367-375.
- Holland, J. M. 1994.** Using fuzzy logic to evaluate environmental threats. *Sensors*. 11: 57-61.
- Jackson, P. 1990.** Introduction to expert systems. Reading, MA: Addison-Wesley Publishers. 526 p.
- Kaufmann, A. 1975.** Introduction to the theory of fuzzy subsets. Volume 1: Fundamental theoretical elements. New York: Academic Press. 416 p.
- Mays, M.D.; Bogardi, I; Bardossy, A. 1997.** Fuzzy logic and risk-based soil interpretations. *Geoderma*. 77: 299-303.
- McBratney, A.B.; Odeh, I.O.A. 1997.** Application of fuzzy sets in soil science: fuzzy logic, fuzzy measurements and fuzzy decisions. *Geoderma*. 77: 85-89.
- Moraczewski, I.R. 1993a.** Fuzzy logic for phytosociology. 1: Syntaxa as vague concepts. *Vegetatio*. 106: 1-12.
- Moraczewski, I.R. 1993b.** Fuzzy logic for phytosociology. 2: Generalizations and prediction. *Vegetatio*. 106: 13-25.
- O'Keefe, R.M., 1985.** Expert systems and operational research mutual benefits. *Operations Research*. 36: 125-129.
- Openshaw, S. 1996.** Fuzzy logic as a new scientific paradigm for doing geography. *Environment & Planning A*. 28: 761-766.
- Ranst, E. Van; Tang, H.; Groenemans, R.; Sinthurahat, S. 1996.** Application of fuzzy logic to land suitability for rubber production in peninsular Thailand. *Geoderma*. 70: 1-9.
- Reynolds, K. 1999.** NetWeaver for EMDS user guide (version 1.1): a knowledge base development system. Gen. Tech. Rep. PNW-GTR-471. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.
- Reynolds, K.; Cunningham, P.; Bednar, L. [and others]. 1996.** A design framework for a knowledge-based information management system for watershed analysis in the Pacific Northwest U.S. *AI Applications*. 10: 9-22.

- Reynolds, K.; Saunders, M.; Miller, B. [and others]. 1997a.** An application framework for decision support in environmental assessment. In: GIS 97 conference proceedings of the eleventh annual symposium on geographic information systems: 1997 Feb. 17-20; Vancouver, BC. Washington, DC: GIS World: 333-337.
- Reynolds, K.; Saunders, M.; Miller, B. [and others]. 1997b.** Knowledge-based decision support in environmental assessment. In: Resource technology 97 conference proceedings: ACSM 57th annual convention; ASPRS 63d annual convention; 1997 April 7-10; Seattle, WA. Bethesda, MD: American Society for Photogrammetry and Remote Sensing; American Congress on Surveying and Mapping: 344-352. Vol. 4.
- Salski, A.; Sperlbaum, C. 1991.** Fuzzy logic approach to modelling in ecosystem research. Lecture Notes in Computer Science. 20: 520-527
- Saunders, M.C.; Coulson, R.N.; Folse, J. 1990.** Applications of artificial intelligence in agriculture and natural resource management. In Kent, A.; Willeams, J., eds. Encyclopedia of computer science and technology: volume 25, supplement 10. New York: Marcel Dekker Inc.: 1-14
- Schmoldt, D.L.; Rauscher, H.M. 1995.** Building knowledge-based systems for natural resource management. New York: Chapman & Hall. 368 p.
- Smith, P.N. 1995.** A fuzzy logic evaluation method for environmental assessment. Journal of Environmental Systems. 24: 275-285.
- Smith, P.N. 1997.** Environmental project evaluation: a fuzzy logic based method. International Journal of Systems Science. 28: 467-474.
- Stone, N.D.; Coulson, R.N.; Frisbie, R.E.; Loh, D.K. 1986.** Expert systems in entomology: three approaches to problem solving. Bulletin of the Entomological Society of America. 32: 161-66.
- Waterman, D.A. 1986.** A guide to expert systems. Reading, MA: Addison-Wesley Publishers. 419 p.
- Zadeh, L.A. 1965.** Fuzzy sets. Information and Control. 8: 338-353.
- Zadeh, L.A. 1968.** Probability measures of fuzzy events. Journal of Mathematical Analysis and Applications, 23: 421-427.



**Zadeh, L.A. 1975a.** The concept of a linguistic variable and its application to approximate reasoning: part I. *Information Science*. 8: 199-249.

**Zadeh, L. A. 1975b.** The concept of a linguistic variable and its application to approximate reasoning: part II. *Information Science*. 8: 301-357.

**Zadeh, L.A. 1976.** The concept of a linguistic variable and its application to approximate reasoning: part III. *Information Science*. 9: 43-80.

**Zadeh, L.A. 1986.** Test-score semantics as a basis for a computational approach to the representation of meaning. *Literary and Linguistic Computing*. 1: 24-35.

**Zadeh, L.A. 1992.** Knowledge representation in fuzzy logic. In: Yager, R.R.; Zadeh, L.A., eds. *An introduction to fuzzy logic applications in intelligent systems*. Boston: Kluwer Academic Publishers: 1-25.

**Zadeh, L. A. 1995.** Discussion—a probabilistic and statistical view of fuzzy methods. *Technometrics*. 37: 271-273.

This page has been left blank intentionally.  
Document continues on next page.

This page has been left blank intentionally.  
Document continues on next page.

This page has been left blank intentionally.  
Document continues on next page.

**Reynolds, Keith M. 1999.** EMDS users guide (version 2.0): knowledge-based decision support for ecological assessment. Gen. Tech. Rep. PNW-GTR-470. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 63 p.

The Ecosystem Management Decision Support (EMDS) system integrates the logical formalism of knowledge-based reasoning into a GIS environment to provide decision support for ecological landscape assessment and evaluation. The system facilitates evaluation of complex, abstract topics such as forest type suitability that depend on numerous, diverse subordinate conditions because EMDS is fundamentally logic based. The object-based architecture of EMDS knowledge bases allows incremental, evolutionary development of complex knowledge representations.

Keywords: Ecosystem management, ecological assessment, knowledge base, decision support, geographic information system, ecosystem analysis, ecosystem states, ecosystem processes.

The **Forest Service** of the U.S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives—as directed by Congress—to provide increasingly greater service to a growing Nation.

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, gender, religion, age, disability, political beliefs, sexual orientation, or marital or family status. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD).

To file a complaint of discrimination, write USDA, Director, Office of Civil Rights, Room 326-W, Whitten Building, 14th and Independence Avenue, SW, Washington, DC 20250-9410 or call (202) 720-5964 (voice and TDD). USDA is an equal opportunity provider and employer.

Pacific Northwest Research Station  
333 S.W. First Avenue  
P.O. Box 3890  
Portland, Oregon 97208-3890



---

U.S. Department of Agriculture  
Pacific Northwest Research Station  
333 S.W. First Avenue  
P.O. Box 3890  
Portland, OR 97208

---

Official Business  
Penalty for Private Use, \$300

**do NOT detach label**

