Contract Report 639

Investigation of the STEWARD Expert System for the Lake Pittsfield Watershed

by
Deva K. Borah

Prepared for the
Illinois Environmental Protection Agency

December 1998

Illinois State Water Survey
Watershed Science Section
Champaign, Illinois

A Division of the Illinois Department of Natural Resources

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Support Technology for Environmental Water and Agricultural Resource Decisions (STEWARD), a knowledge-based (expert) software system is under development at Pennsylvania State University (Penn State) in University Park, Pennsylvania. Michael A. Foster and Paul D. Robillard proposed customizing STEWARD for application in the Lake Pittsfield watershed (personal communication, December 15, 1995). Two versions of STEWARD were mentioned: a non-Geographical Information System (GIS) version (STEWARD) and a GIS version (XGSTEWARD or Expert GIS STEWARD).

The STEWARD Expert system was not available in any form to the investigators of the Lake Pittsfield watershed; it was never customized for this watershed; and therefore it was not used during the investigation. No documentation, publications or references are available about either version of STEWARD mentioned above. However, publications are available on the concepts and descriptions of earlier versions of the systems under different names. STEWARD was previously called RCWP Expert derived from Rural Clean Water Program (RCWP) demonstration projects, and it is described by Robillard et al. (1992), Robillard (1992), Foster et al. (1994), Robillard et al. (1994a), and Robillard et al. (1994b). Zhao et al. (1994) described XGSTEWARD, previously called XGRCWP (Expert GIS Rural Clean Water Programs), which is the UNIX and X-Windows version of the RCWP Expert system.

This report briefly describes RCWP Expert and XGRCWP based on the above documents and publications. Brief descriptions of STEWARD, XGSTEWARD, and their proposed applications to Lake Pittsfield watershed are presented as described and proposed by Foster and Robillard (personal communication, December 15, 1995). There are also discussions of the suitability and usefulness of RCWP Expert (STEWARD) and XGRCWP (XGSTEWARD) for the Lake Pittsfield watershed.

Acknowledgments

This report was prepared using U.S. Environmental Protection Agency funds under Section 319 of the Clean Water Act administered through the Illinois Environmental Protection Agency. Illinois State Water Survey (ISWS) resources also were used in preparation of this report. Robert Sinclair and Abi Akanbi, former scientific staff of the ISWS were the project investigators. After both the investigators' departures from the ISWS through retirement and resignation, the author prepared this report under the direction of Nani Bhowmik, Head of the Watershed Science Section, ISWS, and Chief Derek Winstanley, ISWS. Kingsley Allan collected and provided the documents and information needed to write the report, Eva Kingston edited the report, and Linda Hascall reviewed and formatted the graphics.

STEWARD AND ITS PROPOSED APPLICATION TO THE LAKE PITTSFIELD WATERSHED

The Lake Pittsfield watershed (Figure 1) located in Pike County, Illinois covers 7000 acres (11 square miles) of largely agricultural land use. Land in the western part of the watershed is more rolling with substantial livestock production while the eastern portion of the watershed has a greater proportion of land use in row crops. Lake Pittsfield suffers from significant sedimentation problems, and the upper portion is mostly filled with sediment. Other problems include channel erosion and high nutrient loading in surface runoff. To address the water quality problems in the Lake Pittsfield watershed, the Illinois Environmental Protection Agency (IEPA) proposed to apply STEWARD in combination with the Agricultural Nonpoint Source Pollution (AGNPS) model (Young et al., 1987, 1989):

1. To identify recommended best management practices (BMPs) that should be applied within the watershed.
2. To quantify pollutant loads (nutrients, pesticides, and sediment) under conditions prior to the implementation of actual Section 319 BMPs, subsequent to the implementation of actual Section 319 BMPs, and subsequent to implementation of proposed BMPs recommended by STEWARD.
3. To evaluate the effectiveness of actual and simulated BMPs.
4. To determine the functional value of the STEWARD system for satisfying the aforementioned purposes.

Under this contract, the ISWS was directed to develop and implement a strategy for the application of STEWARD and AGNPS. This strategy was required to identify the computer hardware and software requirements for the application of these system and model, including the need to establish a GIS (ARC/INFO) interface with the system and model, test the operational level of STEWARD, and adapt STEWARD to function under conditions of the Midwest. The strategy was to identify the informational requirements (i.e., contaminant characteristics, water quality monitoring data, contaminant transport processes, nutrient and pesticide applications, climate data, soil characteristics, farm management practices, topography, and hydrology) for the application of the system and model. The strategy was to identify the tasks, costs, and schedule for satisfying all the requirements for the application of the system and model, and discuss any barriers to the satisfaction of these requirements (including any arrangements that must be negotiated with Penn State).

STEWARD is intended to assist watershed project teams in site-specific selection and evaluation of nonpoint source (NPS) control systems in agricultural watersheds. STEWARD is based on information learned from the Rural Clean Water Program (RCWP) demonstration projects, a ten-year program that studied NPS pollution in 21 agricultural watersheds throughout the United States (Robillard et al., 1992). The studies involved long-term water quality monitoring and implementation of nutrient, sediment, and pesticide reduction practices.

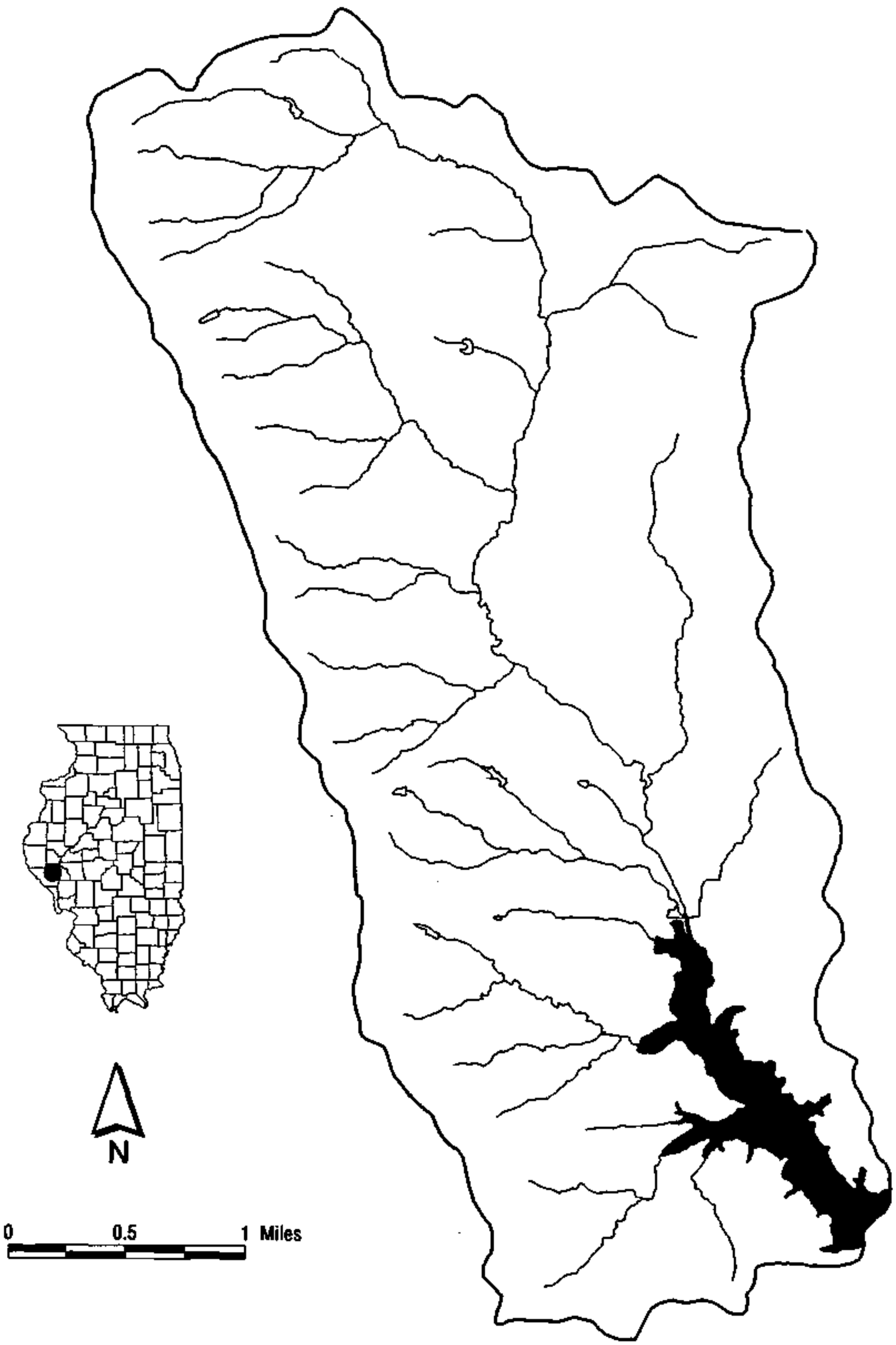

Figure 1. Lake Pittsfield and its watershed and contributing streams

Foster and Robillard (personal communication, December 15, 1995) mentioned two versions of STEWARD: a non-GIS version (simply called STEWARD) and a GIS version (XGSTEWARD or expert GIS STEWARD). STEWARD recommends control systems at a single site and enables the user to query an NPS relational database to compare effectiveness of alternative control systems. In addition, there are hypertext reference modules with educational materials on monitoring, transport, drinking water contaminants, case studies from the RCWP watershed demonstration projects, and water quality databases. STEWARD is written in Hyper Text Markup Language (HTML) so that it can be run on a World Wide Web (WWW) server using the HTTP protocol and viewed through WWW browsers.

XGSTEWARD is the spatially referenced (GIS-based) version of STEWARD. It retains STEWARD'S core functions of site-specific control systems recommendations and database evaluation of control systems' effectiveness, and adds more features. Its software environment is a Geographic Resource Analysis Support System (GRASS) 4.1 (GIS) and INFORMIX 4.1 Relational Database Management System (RDBMS) on a Sun Operating System 4.3.1 with an X-Windows (X11R5, Motif 1.2.2) interface, and a UNIX version of the AGNPS model. Foster and Robillard (personal communication, December 15, 1995) indicated that by the spring of 1996, XGSTEWARD would be updated to run on the newer Solaris 2.5 operating system for Sun workstations. Distinct components would be:

- Critical area analysis to prioritize among sites based on AGNPS model runs or sample data,

- An expert system that recommends control systems based on site-specific data from user dialogs or the GIS database,

- Links to the AGNPS water quality model and to STEWARD'S NPS database for evaluating potential control systems' effectiveness, and

- Links to STEWARD'S informational hypertext reference modules.

Also, in the above communication, Foster and Robillard proposed customizing STEWARD and XGSTEWARD for the Lake Pittsfield project and convert XGSTEWARD from use of GRASS 4.1 to ARC/INFO, a GIS software package for spatial data and analysis. This would involve:

- Customization of expert rules for control systems recommendation and configuration in the single site, non-GIS STEWARD.

- Conversion of the (GIS-based) XGSTEWARD and Penn State GIS interface to AGNPS from GRASS 4.1 to ARC/INFO.

STEWARD is being developed at Penn State as a knowledge-based expert system incorporating and integrating human expertise and important spatial and rational data for NPS management projects in watersheds. The knowledge and the expert rules for critical area analysis and for siting and selection of control systems were originally developed from the RCWP for a largely agricultural NPS context. These rules need to be revised for the Lake Pittsfield watershed to reflect additional subsets of land uses and pollutant concerns. The proposed strategy of Foster and Robillard was to review carefully the existing rules in STEWARD with experts from the Lake Pittsfield watershed project, the IEPA, and the ISWS during structured sessions to determine the revisions and modifications required for the Lake Pittsfield watershed project. Once the watershed team and the selected experts agreed on the expert rule modifications, those would be incorporated into the Lake Pittsfield version of STEWARD.

XGSTEWARD currently uses GRASS 4.1 GIS and INFORMIX 4.1 RDBMS for soils, field borders, land use, and hydrology for the Sycamore Creek watershed, Ingham County, Michigan. The Penn State project team proposed to assist the ISWS team in developing ARC/INFO databases for the Lake Pittsfield watershed of similar structure and content for use by the ARC/INFO converted version of XGSTEWARD. In the current GRASS 4.1 GIS-based version of XGSTEWARD, expert rules for critical area delineation, pollutant loading functions, expert rules for control systems siting and selection, and the GIS interface to AGNPS are all based on UNIX shell script, C language, and GRASS 4.1 GIS functions. The Penn State team is to re-script the overall graphical interface of XGRCWP in ArcView, a GIS software package, with Avenue-based script and all other functions to be re-scripted in either Avenue or Arc Macro Language (AML).

RCWP EXPERT

Foster et al. (1994) comprehensively describe RCWP Expert, which is thoroughly reviewed and summarized here. As described earlier in context to STEWARD, RCWP Expert is the previous version of STEWARD, and is a knowledge-based software system designed to assist watershed project teams in the selection and implementation of water quality control practices in agricultural watersheds. The RCWP Expert knowledge base is derived from the results of the RCWP demonstration projects conducted at 21 sites throughout the United States during a 10-year period. The RCWP was initiated by the U.S. Department of Agriculture (USDA) in 1981 with the following objectives:

- To achieve improved water quality in a cost-effective, environmentally sound manner.
- To assist agricultural managers in reducing NPS pollutants and improving rural water quality.
- To develop and test programs, policies, and procedures for the control of agricultural NPS pollution.

NPS pollution generally results from surface runoff, precipitation, drainage, or seepage rather than from a discharge at a specific, single location, except for agricultural storm water discharges and irrigation return flows. The RCWP effort represents comprehensive, long-term water quality monitoring and implementation of nutrient, sediment, and pesticide reduction practices in the United States. The 21 RCWP project sites received long-term financial and technical assistance from USDA for installation and maintenance of control practices.

Among the major lessons learned by the RCWP project teams from the RCWP projects are:

- Implementation of control practices should be targeted to critical areas where problem pollutants and their major sources have been identified.
- Water quality and land treatment monitoring should be conducted in a controlled manner so that project success can be tracked by systematic comparison of water quality data with pre-treatment and concurrent control data (the paired watershed approach).
- Modeling techniques (e.g., AGNPS) can be used to identify critical areas, set priorities, and determine practice implementation strategies.
- Nutrient and water budgeting techniques can be used to quantify pollutants and their sources, such as relative contribution of point versus nonpoint sources, and surface

water versus groundwater. Accurate budgeting requires an understanding of chemical transformations, movement, storage, and fate.

The lessons learned from the RCWP about targeting of critical areas, monitoring systems, and design and implementation of control practices for NPS control need to be properly integrated and packaged in an easily accessible form that leads to the development of RCWP Expert system. Advantages of such an expert system could be enormous, for example, a flexible intuitive interface, an easily maintained and updated knowledge base, and the ability to link to other knowledge bases and software systems for further synthesis and integration. The RCWP Expert system is targeted for users who design and select practices to control NPS contaminant loading from agricultural watersheds.

Development of RCWP Expert System

The RCWP Expert system was implemented by Foster et al. (1994) on Apple Macintosh computers running standard Macintosh Operating System 7.x. The architecture consists of three main components (Figure 2): (1) Control Systems, (2) Reference modules, and (3) the NPS Database. The Control System module recommends complementary sets of practices based on site-specific characteristics. These complementary sets of control practices are referred to as control systems. After the Control System recommends alternative control systems, the user can query a relational database of published studies (NPS Database) to compare potential effectiveness of the recommended control systems. Several hypertext reference modules provide general principles and explanatory information relevant to the RCWP Expert system (Figure 2):

- Module on 55 drinking water contaminants with submodules: Environmental Fate, Health Effects, Testing, and Treatment.

- Monitoring module on water quality monitoring systems.

- Transport module on contaminant transport variables.

- Case Studies module on 21 RCWP sites from five regions of the United States.

- Water Quality module on other water quality databases.

The primary software environment of RCWP Expert is hypermedia, an expanded form of hypertext. In contrast to the linear structure of standard document organization, hypertext consists of related nodes or chunks of text connected to each other by electronic cross references or links in a natural, associative fashion. When the nodes are other media as well such as graphics, animation, and sound, the term used is hypermedia. RCWP Expert is a hypermedia application since its nodes (individual screens) contain extensive graphics and text. The hypermedia system used in RCWP Expert is OracleCard, which provides an intuitive interface of menus, buttons, and icons for the user to navigate

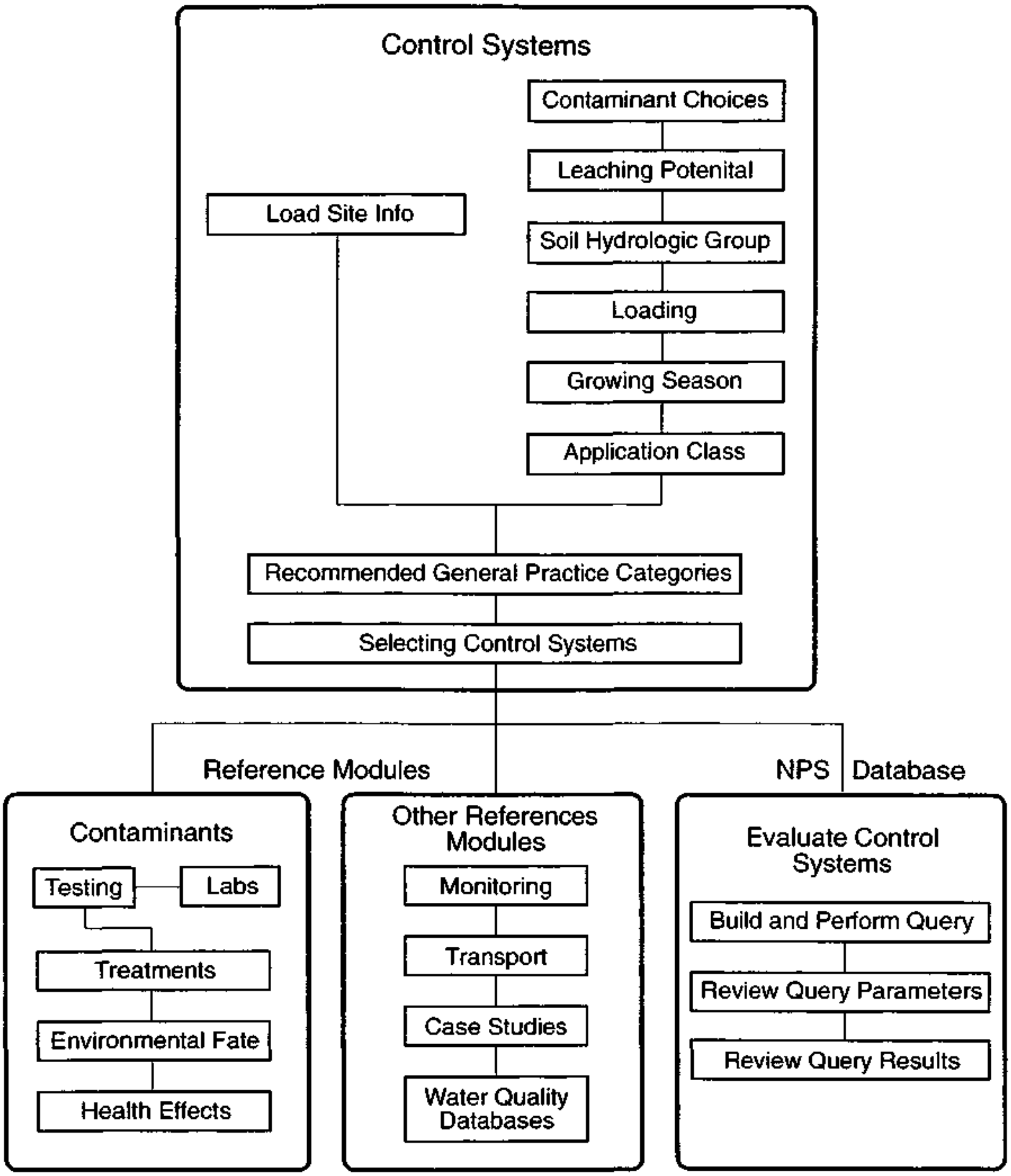

Figure 2. Overview of RCWP Expert System: Control Sytem module, Hypertext reference modules, and Nonpoint Source Database

through associative links between text chunks or graphics. OracleCard on the Macintosh can perform Structured Query Language (SQL) queries with ORACLE relational databases and an intuitive hypermedia interface.

Knowledge Sources and Knowledge/Data Acquisition Methods. The knowledge and data for RCWP Expert are derived primarily from published studies and reports. The logic for the Control Systems module is based on principles learned from the RCWP project sites, which relate site-specific conditions to recommended control practices. The RCWP Expert developers (Foster et al., 1994) converted these principles to dependency networks of AND/OR diagrams, which are graphical representations of expert system IF-THEN rules (Figure 3). Since there were only 23 rules in the RCWP Expert system component, these are implemented in the scripting language of OracleCard and PLUS Programming Language (PPL) rather than developed with a specialized RCWP Expert system shell.

The NPS Database available to the RCWP Expert developers consists of information summarized from 202 of the 700 articles reviewed on water quality control practices. During a two-year period, several readers identified published studies that included high-quality practice effectiveness data and adequate experimental controls. Each article that met data quality and experimental/statistical standards was assigned a unique reference identification (ID) number called Sequential Article Number (SAN), and the following information was recorded for the article:

- Number of distinct experimental treatments.
- Soil Conservation Services (SCS) technical practice codes applied in each treatment (specific version of the practices).
- Contaminants affected by the practices (e.g., nitrate or sediment).
- Site-specific characteristics (e.g., soil hydrologic group or climate rain zone).
- Contaminant load and concentration before practices were applied.
- Percent change in contaminant load and concentration after practices were applied.

All of the information for each record was then divided among several relational tables. The overall database structure is described below.

The RCWP Expert developers derived the information for the Contaminants hypertext reference modules (Environmental Fate, Health Effects, Testing, and Treatments) from 90 journal articles, books, U.S. Environmental Protection Agency (USEPA) reports, and World Health Organization documents. The Transport reference module is based on literature concerning agriculture and water quality. Sources for the

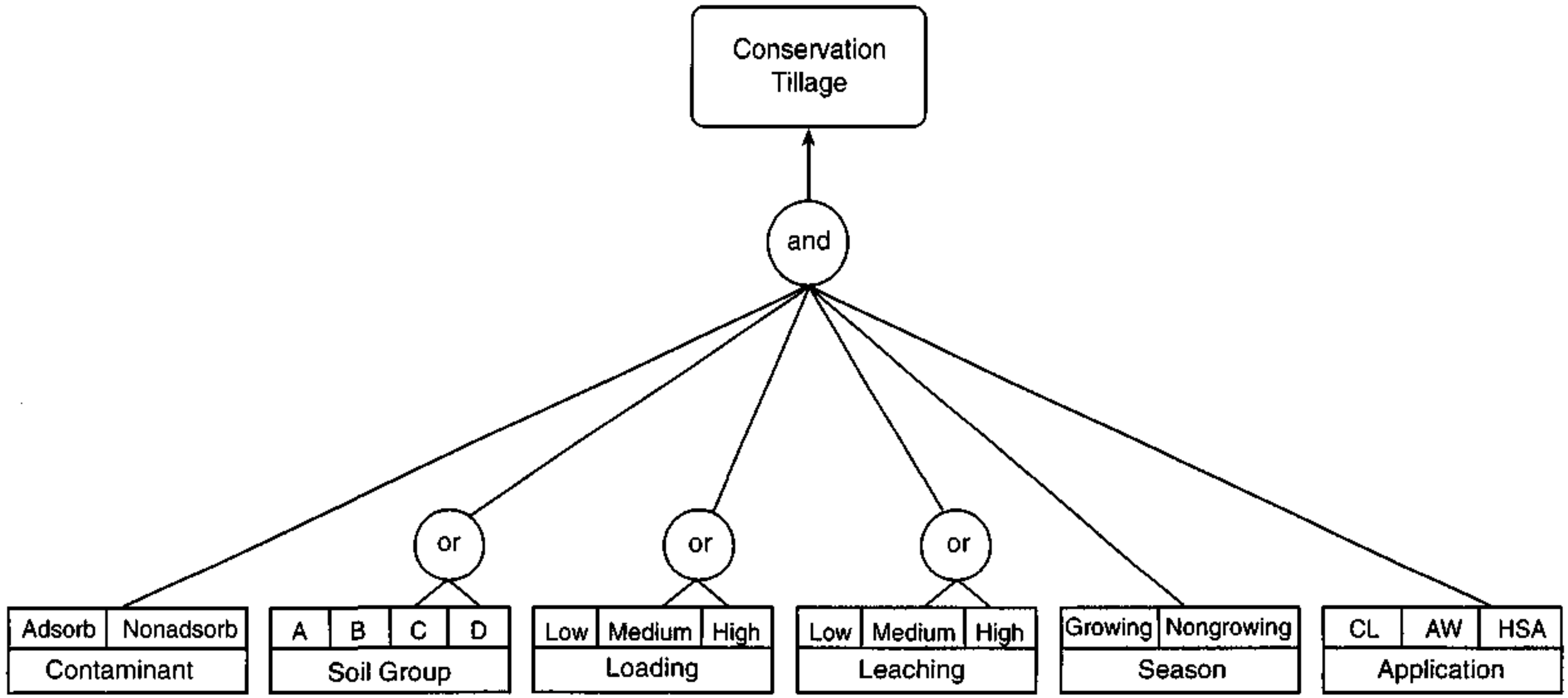

Figure 3. Dependency network (AND/OR diagram) of RCWP Expert System for site-specific recommendation of conservation tillage

Monitoring reference module consist of literature that specifically covers monitoring systems and general statistics. The Case Studies reference module is based on the annual, ten-year, and final reports of the various RCWP projects. The primary source of information for the Water Quality Databases module is the proceedings of a February 5-8, 1990 workshop on "Information Exchange on Models and Data Needs Relating to the Impact of Agricultural Practices on Water Quality," at Reston, Virginia, organized by the U.S. Geological Survey (USGS), U.S. Department of Agriculture (USDA)-Agricultural Research Services (ARS), and USDA-SCS (USGS et al., 1990).

Control Systems Module: Selection and Evaluation

The primary target users of RCWP Expert are the watershed project teams responsible for monitoring, evaluation, and implementation of NPS controls. Effective farm plans for an agricultural watershed must include control practices for nutrient, pesticide, and sediment loads that consider the following:

- Specific contaminants of greatest concern at each site.
- Site-specific hydrologic, soil, crop, tillage, and management factors.
- Interactions among these site-specific factors.
- Impact of the factors and their interactions on contaminant solubility, soil adsorption properties, toxicity, and persistence.

Control System Selection with the RCWP Expert System. The knowledge-based RCWP Expert system is divided into two distinct parts:

1. IF-THEN rules for recommending control practices based on site-specific characteristics.
2. Reference tables of feasible, complementary combinations of control practices termed "practice sets" or "control systems".

Four main criteria are considered in recommendation of candidate control practices for a given contaminant and set of site characteristics. These are:

1. The practices must be able to control the transport pathway of the contaminants. Possible transport pathways are overland flow, percolation, erosion, and sedimentation. The relevant pathway for a contaminant depends primarily on its adsorption characteristics. Practices that control erosion and sedimentation pertain to strongly adsorbed contaminants such as trifluralin. Those practices that have an impact upon soil erosion and overland flow are appropriate for moderately adsorbed contaminants such as Malathion. The appropriate practices for nonadsorbed

contaminants, such as nitrate-nitrogen, are those directed at deep percolation and subsurface flow.

2. The practices have to be compatible with the farm management system already in place.

3. The practices must be technically feasible (e.g., contour farming is difficult on complex slopes, and reduced tillage is not recommended on poorly drained soils).

4. The practices must be socioeconomically feasible (e.g., market conditions may not permit use of new crop varieties or field rotations).

Once candidate control practices are recommended, quantitative evaluation is completed to select the best control practice or system.

In RCWP Expert system terminology, the contaminant of interest and other site characteristics are the "antecedents" of the rules, while the recommended control practices are the "consequences" of the rules. The site-specific characteristics used by the RCWP Expert rules are:

- The adsorbance of the contaminant, which can be one of 12 contaminants ranging from pesticide classes (strong, moderate, weak, and nonadsorbed) to nutrients (ammonia, total nitrogen, total phosphorus, and orthophosphorus) to biological agents (bacteria and viruses) to sediment.

- Potential for contaminant loading (low, medium, and high), potential for contaminant leaching (low, medium, and high), soil hydrologic group (A, B, C, and D), time of year (growing or nongrowing season), and the application class (e.g., land use: cropland or animal waste).

The user chooses a contaminant of concern for the given site, then selects the appropriate choice for the five other site characteristics. The RCWP Expert system then recommends a set of candidate control practices for that site.

Eighteen general categories of control practices were used in the RCWP projects, of which 11 categories were used in the RCWP Expert system. These 11 categories are classified in one of four stages of the contaminant transport pathway: source, field, transfer, and delivery as listed in Table 1 and explained below.

Source controls, such as nutrient (fertilizer or manure) or pesticide management, typically involve changes in application rate, timing, and application technique. Field controls, such as conservation tillage, strip cropping, and permanent vegetative cover, make use of structural and vegetative control mechanisms to reduce runoff and soil erosion. Transfer controls, such as animal waste systems that transfer potential contaminants off-site provide facilities for the storage and collection of animal waste to abate pollution that may otherwise result from livestock or poultry operations. Delivery controls are targeted at the actual point(s) of discharge of contaminants into streams, rivers, lakes, and groundwater. One type of delivery-based control is a diversion system of earth channels constructed across a slope to collect water and prevent damage to an area below it. Other delivery controls are sediment retention basins and water control structures.

The RCWP Expert system has 23 rules for site-specific recommendation of control practices. Each rule represents a unique set of site-specific conditions, with 1-5 rules or sets of conditions resulting in recommendation of a particular control practice. For example, conservation tillage is recommended to reduce contaminant loading from erosion and runoff for four different sets of conditions. Conversely, several control practices are often recommended for the same set of site-specific conditions. When the contamination of interest is total nitrogen, and site conditions are cropland land use, low leaching potential, soil hydrologic group B, low contaminant loading, and growing season, the recommended control practices are diversion, terraces, conservation tillage, waterways, and nutrient management.

Table 1. Control Practices Used in RCWP Expert

Contaminant pathway	*Control practices*
Source	Nutrient Management (NUTR)
	Pesticide Management (PEST)
Field	Conservation Tillage (CT)
	Permanent Vegetative Cover (PVC)
	Stream Protection (SP)
	Strip Cropping (SCR)
Transfer	Animal Waste System (AWS)
Delivery	Diversion System (DIV)
	Sediment Retention and Water Control (SED)
	Terrace Systems (TERR)
	Waterway Systems (WATW)

During the initial stages of the RCWP, specific control practices were used to reduce contamination, primarily at the field phase of contaminant transport. However, the concept of control systems evolved at a few RCWP sites at which multiple practice types were implemented (source, field, transfer, and delivery) in order to control all possible phases of contaminant transport between the source and the point of impact at a given site. Accordingly, RCWP Expert system goes beyond recommendation of single control practices to assist in the selection of control systems and first recommends all control practices indicated by the RCWP Expert rules. Next, the user receives a set of possible alternative control systems constructed by the RCWP Expert system by comparing the recommended list of single practices with a reference table of possible control systems for the land use (cropland, animal waste, and high source area). The user then selects particular control systems, such as nutrient management (source), strip cropping (field), and waterways (delivery) for detailed evaluation. Evaluation is provided by querying the NPS Database, as described below.

Control System Evaluation with the Nonpoint Source Database. The NPS Database is a relational database in Oracle for the Macintosh that contains 202 published studies with data on control practice effectiveness. Each literature citation is assigned a unique sequential article number (SAN) and a treatment number within SAN for each distinct treatment. For example, all information pertaining to treatment 1 of literature citation 313 has the unique ID number 313.1. The total information for each treatment within each citation comprises a "super-record," which is divided into smaller records among four main types of tables (35 tables in all): a table of bibliographic information, a table for each of the 20 contaminants (e.g., total nitrogen and total phosphorus), a table for site-specific characteristics (e.g., soil hydrologic group and climatic rain zone) and other information (e.g., control practice costs, crop characteristics, soil erosion potentials/parameters, etc.). All records in all tables are uniquely identified by SAN and treatment number (e.g., 313.1), which enables joining of records across tables during a database query. Records in all contaminant tables (e.g., total nitrogen and total phosphorus) also contain a general description of the treatment applied, the SCS technical code for the control practices, a description of that control practice, contaminant mass load and concentration before the practice was applied, and percent change in contaminant mass load and concentration after the practice was applied. The NPS Database is organized to optimize database queries of the following general form:

"Give me a summary of control effectiveness data for SCS technical codes aaa, bbb, ... (3-digit codes), contaminant Y (only one contaminant type per query), and site-specific parameters SI, S2, ...".

The user can query the NPS Database for general information on control practice effectiveness. Alternatively, the user can structure and execute directed database queries to compare the potential effectiveness of alternative control systems recommended by RCWP Expert. The steps in using the NPS Database for purposes of control system evaluation are as follows:

1. Execute an Expert systems consultation with RCWP Expert to obtain a list of recommended control practices and control systems for the contaminant and site of interest.

2. Select a particular control system for detailed evaluation.

3. Select general practice categories and specific versions of those control practices (i.e., USDA-SCS technical practice code) from the selected control system.

4. Select the contaminant of interest for the site where control practices are to be applied (by default, the contaminant originally specified for the Expert system session).

5. Specify the site characteristics.

6. Execute the query and view the query results.

A graphical interface to the NPS Database enables the user to specify database query criteria by selecting a series of options in scrolling lists and buttons. Through interaction with this interface, the user generates the appropriate SQL query, which is then submitted to the database. The result of the query is a statistical summary of control practice effectiveness for the given contaminant, control practices, and site characteristics, which is displayed to the user and can be saved in a text file. In order to compare potential effectiveness among several control systems recommended by RCWP Expert, the user query process can be repeated for each control system.

Reference Modules

Contaminants. The Contaminant module consists of four submodules (Table 2) for 55 drinking water contaminants:

- **Environmental Fate:** This submodule describes each contaminant's potential for becoming a drinking water problem, its physical attributes and use, how it breaks down in the environment (degradation), and the potential for its persistence in the environment.

- **Health Effects:** This submodule covers only 21 of the 55 contaminants because of the limited information available on standards and risk levels. It contains USEPA standards for the 21 contaminants, health effects after accidental or experimental human exposure, possible sources of exposure, reports on past contamination incidents, and advisories on what to do about a specific contamination problem.

- **Testing:** This submodule provides advice on how to take water samples for testing, the cost of different procedures, and locations of appropriate water testing laboratories.

- **Treatment:** This submodule provides an overview of various water treatment devices for home use, including their effectiveness and relative cost, and contains maximum contaminant concentration levels allowed by the USEPA.

Table 2. Topics Covered in Reference Modules and Submodules

Reference module	*Submodules*	*Topics*
Contaminants	Environmental Fate	Potential for problem, attributes and use, degradation, and persistence
	Health Effects	USEPA standards, health effects from exposure, sources, and advisories
	Testing	Sampling, costs, and testing laboratory locations
	Treatment	Overview of treatment devices and contaminant limits allowed by USEPA
Monitoring	Systems	Monitoring systems design and information flow
	Parameters	Parameter selection and contaminant properties
	Sampling	Equipment and methodology
	Analysis	Sample handling, chemical analysis, quality assurance, and reporting
	Loading	Loading and flow calculations and concepts
	Statistical Analysis	A primer on statistical topics pertinent to monitoring
Transport		Surface flow Subsurface and groundwater flow Adsorption and solubility Critical events Delivery Control mechanisms
Case Studies	Background information	Site characteristics, land use, animal operations, and critical areas
	Water Quality	Problems and goals
	Activities	Control practices, effectiveness, and monitoring methods
	Economics	Budget and cost sharing among agencies, and potential economic benefits
	Summary	Lessons learned and water quality impact
	References	Published reports
Water Quality Databases		Descriptions of 92 water quality databases

The user may consult any combination of these modules to assist in advising a homeowner or agricultural producer about a contaminant problem. Watershed applications encourage use of the contaminant module during a control systems planning session to emphasize to a farmer or a rural resident which contaminants are the most likely to be found in his/her water supply based on the type of agricultural activity in recharge zones.

Monitoring. One of the key lessons learned from the RCWP demonstration projects is that properly designed, evaluated, and documented water quality monitoring and correlation with land-use and control practices are critically important for identifying a water quality problem and for evaluating control practice effectiveness. Similarly, land use, control practices, and water quality must be tracked jointly. Key elements of a successful monitoring program are:

- A problem identification monitoring program lasting for 6-18 months to identify the water quality problem, pollutants and conditions responsible,
- Clearly stated monitoring objectives based on problem identification,
- An effective and statistically valid monitoring design (sampling station locations and frequency, intensive land treatment and land-use tracking, and inclusion of all relevant variables), including spatial and temporal considerations,
- Adequate laboratory and field data quality assurance and quality control, and
- Well-organized and integrated computer-based data management analysis.

The above topics are covered in several sections of the Monitoring reference module (Table 2): systems, parameters, sampling, analysis, loading, and statistical analysis.

Transport. Contaminant transport from nonpoint sources to water bodies is by overland flow, leaching and subsurface flow, erosion, and sedimentation. Because control practice impact on contaminant transport pathways is key in selecting a practice, it is critically important for land treatment designers to understand the relationships between contaminant characteristics, site characteristics such as soil properties that interact with the contaminant, contaminant transport processes, and control practices. These essential topics are covered in the Transport reference module, which describes surface and groundwater contaminant pathways, and contaminant solubility and adsorption processes, all within the context of control mechanisms and options. Contaminant loading and critical loading periods are also described. Six main topics covered (Table 2) are: surface flow, subsurface and groundwater flow, adsorption and solubility, critical events, delivery, and control mechanisms.

Case Studies. The Case Studies module illustrates the general principles learned about water quality management from 21 RCWP sites with summary information from each of the studies. The main topics covered in hypertext form for each site are: background information, water quality, activities, economics, summary, and references (Table 2). The user can navigate through these hierarchically structured topics to find a similar situation and the methods used to alleviate it.

Water Quality Databases. The Water Quality Database module consists of brief descriptions of 92 different databases relevant to water quality and environmental issues. The user clicks on the Main Menu button to display the available choices in a scrolling field. After the user makes the selection (for example, the Civil Engineering Database), the system displays the following topics for that particular database in a scrolling field: Full System Name, Data Types, Responsible Agency, Database Description, Users Manual, Availability, Communications and Format, and Contact Person or Organization.

Sample Consultation with RCWP Expert

In order to illustrate how RCWP Expert might assist in control systems selection and evaluation, a case study of an actual RCWP project site, St. Albans Bay, Vermont, is presented. St. Albans Bay watershed is located in Franklin County in northwestern Vermont, 25 miles north of Burlington. This watershed drains approximately 50 square miles of agricultural (65%), forested (20%), and urban/residential land (10%) into St. Albans Bay. Dairy farming is the primary agricultural activity, with 102 operating dairy farms and an average herd size of 110 animals as of 1990. Other fanning operations include a few fruit and vegetable farms and horse farms. Corn for silage is the principal cultivated crop, about 10-15 percent of the total watershed area, while hay covers about 30-35 percent of the watershed area. During the RCWP (1980-1990), nutrient (phosphorus and nitrogen) runoff to St. Albans Bay from improper manure management (year-round spreading due to lack of waste storage and inadequate milkhouse waste and barnyard runoff management), exacerbated by improper fertilizer management, were identified as the major contributors to water quality degradation. Cropland soil erosion, resulting in high turbidity, was also a concern. Consequently, recreation in the area suffered, shoreline property value declined, significant macrophyte growth occurred, and there were fish kills.

The primary goal of the St. Albans Bay RCWP project was the improvement of water quality in St. Albans Bay and the restoration of beneficial uses by implementing control practices to reduce nutrients and sediment loading to surface waters. The most widely implemented land treatments (control practices) on 102 farms during the RCWP were animal waste management (construction of manure storage facilities, barnyard runoff control, and milkhouse waste treatment) and cropland protection (protection from erosion between crops or prior to long-term vegetative cover). A total of 64 manure storage systems, 61 barnyard runoff control systems, and 43 milkhouse waste treatment systems were installed. Despite widespread practice implementation and significant phosphorus load reduction from a wastewater treatment plant, St. Albans Bay water quality improved slightly in the innermost part of the bay but declined slightly elsewhere. Project coordinators at St. Albans Bay suggest greater success could have been achieved by considering management issues after storage facilities construction such as:

- Location, timing, application rate, and soil incorporation (source control),
- A 12-month storage facility rather than 5-6 month facility (transfer control), and
- Controlled livestock access to surface waters (i.e., fencing cows out of streams; delivery control).

In addition, it is possible that contaminant loads from just a few nonparticipating farms (e.g., winter manure spreading) overwhelmed upland treatment effects. Finally, the lag time between land treatments and water quality improvements may have exceeded the monitoring period.

The sample consultation with RCWP Expert that follows is tailored to the water quality problems and goals of the St. Albans Bay RCWP. The scenario considered includes the contaminant TOTAL PHOSPHOROUS for the land use HIGH-SOURCE AREA (e.g., waste-contaminated runoff from dairies) with HIGH LOADING POTENTIAL. High clay content and poor drainage predominate in St. Albans Bay so LOW LEACHING POTENTIAL and SOIL HYDROLOGIC GROUP D are entered as site characteristics. To further intensify the problem of waste-contaminated runoff, the time of year specified is NONGROWING SEASON (for example, spring when ground is still frozen and there is little percolation). The user specified these conditions in response to the dialogue screens of the Control Systems module, which has recommended ANIMAL WASTE (storage or land-based) and DIVERSION as general categories of control practices for further evaluation (Figure 4). The user can now evaluate potential control practice effectiveness by selecting one or more specific SCS technical codes for ANIMAL WASTE management or DIVERSION, then querying the NPS Database for literature on practice effectiveness. In the example shown (Figure 5), the user has selected WASTE TREATMENT LAGOON (code 359) and WASTE STORAGE STRUCTURE (code 313), for evaluation. The NPS Database query results were equivocal, an average of 3 percent reduction in phosphorous load (5 studies) following implementation (Figure 6). Note that a type of animal waste system not commonly used in St. Albans Bay, filter strips (code 393), appears for more effective, with 77 percent load reduction of total phosphorous in 13 studies. Filter strips are strips or areas of vegetation which remove sediment, organic matter, and other contaminants from runoff and waste water.

RCWP Report Name: Recommendations for St. Albans Bay

SITE-SPECIFIC RECOMMENDATIONS FOR ST. ALBANS BAY, VERMONT

Contaminants:
Total Phosphorus

Site Characteristics:

Application Class:	high-source-area
Leaching Potential:	low
Soil Hydraulic Group:	Soil D
Contaminant Loading:	high
Season:	nongrowing

Recommended General Practice Categories:
Animal Waste System (land application)
Animal Waste system (storage)
Diversion

Figure 4. Control practices recommended by RCWP Expert System in the context of the St. Albans Bay case study

Query Builder for NPS Database: Review Selections

Click on the SCS Code Number to display SCS descriptions

Query Parameters
BMPs 313 - Waste Storage Structure 359 - Waste Treatment Lagoon CONTAMINANTS Total Phosphorus

Figure 5. Review screen for Nonpoint Source Database query

DATABASE QUERY FOR SAINT ALBANS BAY, VERMONT

CONTAMINANTS;
Total Phosphorus

SAN	TPC	TPCP	TPL	TPLP		SCSCODE
245.12	7.2					312 359
249.1			3.72			359
249.2			1			359
249.3			0.87			359
284.12				3.2		313
284.13				0.8		313
284.15				6.2		313
284.2				0.5		313
284.4				4.9		313
STATISTICAL SUMMARY						
AVG	7.20	0.00	1.86	3.12	0.00	0.00
STDV	0.00	0.00	1.61	2.50	0.00	0.00
MIN	7.20	0.00	0.87	0.50	0.00	0.00
MAX	7.20	0.00	3.72	6.20	0.00	0.00
Counts	1	0	3	5	0	0

Figure 6. Results for the Nonpoint Source Database query specified in Figure 5

The user may then wish to examine the Transport reference module to learn why storage structures may not be effective without subsequent management of manure application (e.g., nutrient management), erosion (e.g., conservation tillage), or runoff (e.g., filter strips). This module teaches the user that total phosphorous is strongly absorbed to sediment. Even with proper storage, excessive manure application to fields, particularly during the hydrologically active late winter/early spring period, can cause excessive loading to surface waters, resulting in accelerated algal growth that kills fish by severe depletion of dissolved oxygen. Source-based controls, such as properly incorporated manure, moderate or split applications, or delivery-based controls such as filter strips, can further reduce unnecessary loss.

The user may also wish to consult the Monitoring reference module to ensure adequate control sites, sampling methodology, and monitoring periods. Finally, users may wish to consult other databases listed in the Water Quality Databases module, such as USEPA's STORET Water Quality Database, for additional data that relate to their particular situation.

XGRCWP: EXPERT GIS RCWP

XGRCWP, Expert GIS RCWP is an expert system that integrates GIS, a relational database, simulation models, and HTML documents to form an advisory system for the selection, evaluation, siting, and design of NPS pollution control systems in agricultural watersheds. Zhao et al. (1994) describe the expert system, which is reviewed and summarized here. Its major features include:

- Customized GIS functions to obtain spatial and attribute data and input them to a rule-based expert system for selecting feasible control practices.
- A user interface for examining the field-specific conditions and recommended control practices on the screen by clicking on the displayed field boundary map.
- A direct linkage between the GIS spatial data and the relational attribute data that allow the user to examine data on the screen interactively.
- A graphical user interface (GUI) to GIS functions that enables the user to perform various routine watershed analyses.
- Links to hypertext reference modules viewable by Mosaic Internet document browser, and
- Dynamic access to other models such as AGNPS.

The software environment of XGRCWP is GRASS 4.1 GIS and X-Windows on Sun Operating System 4.3.1. The XGRCWP major functions have been tested for the Sycamore Creek watershed in Ingham County, Michigan. XGRCWP is composed of five major components:

1. An Expert GIS RCWP system for recommending control practices based on site-specific information,
2. Custom and existing GIS functions for watershed analysis and estimation of contaminant loading potential,
3. Links to fields, soils and land-use databases,
4. Links to the AGNPS model, and
5. The Hyper Text Markup Language (HTML) reference module.

The graphical user interface integrates the five components and provides the user with flexibility to navigate them. The components are also internally connected in different ways. For example, the Expert GIS RCWP system can use the customized GIS functions to retrieve site-specific information from GRASS 4.1 data layers and INFORMIX 4.1 relational database tables. In addition, the Expert GIS RCWP recommendations of control practices can be displayed and examined by GRASS 4.1 function. Finally, the GIS functions can help generate input to the AGNPS model, and its output can be converted to GIS format for additional analyses.

Design of the Expert System

The objective of the Expert GIS RCWP system is to recommend feasible control systems, i.e., complementary sets of control practices to reduce NPS pollution based on site-specific conditions. One distinct feature of this system is the combination of two modes of data acquisition: direct user input, and GIS function. XGRCWP also has two modes for deriving the expert recommendations: batch or interactive. These aspects of the expert system as well as its knowledge base are discussed below.

Rules for Control Practice Selection. The knowledge base of the Expert GIS RCWP system includes the following six site-specific characteristics:

1. The contaminant of interest and its adsorption characteristics.

2. Potential level of contaminant loading (low, medium, or high).

3. Potential level of contaminant leaching (low, medium, or high).

4. Soil hydrologic group (A, B, C, or D).

5. Time of year (growing season or nongrowing season).

6. Type of land use (cropland or animal waste).

The user first chooses a contaminant of his/her current interest from a list consisting of four kinds of pesticides (strongly, moderately, or weakly adsorbed, and non-adsorbed) and eight other contaminants (ammonia, bacteria, sediment, total nitrogen, total phosphorous, nitrate, orthophosphate, and viruses). The values of other characteristics, some of which vary with the contaminant specified, then can be input either directly by the user or by custom GRASS functions as discussed below under "Data Acquisition."

The RCWP projects used 14 general categories of control practices (Table 3). A number of suitable conditions have been established for each general category. For example, some form of conservation tillage is recommended to reduce runoff for cropland under conditions otherwise favoring loss through sediment transport, such as a contaminant strongly adsorbed to the soil (e.g., total phosphorous), the nongrowing season, and soils with a relatively high runoff potential (e.g., soil group C or D). Each general category includes several specific control practices. When a general practice

Table 3. Best Management Practices Used in the RCWP

Practice category	*Best management practices*
Source control	Nutrient management (NUTR)
	Pesticide management (PEST)
Structural control	Animal waste system (AWS)
	Diversion systems (DIV)
	Sediment retention and water control (SED)
	Terrace systems (TERR)
	Waterway systems (WATW)
Vegetative control	Conservation tillage (CT)
	Critical area treatment (CAT)
	Cropland protection systems (CPS)
	Grazing land protection (GLP)
	Permanent vegetative cover (PVC)
	Stream protection (SP)
	Strip cropping (SCR)

category is recommended, the user has to decide which specific practice within that general category is to be evaluated further by consulting the NPS Database for the reported research data about this practice or by running the AGNPS model.

Data Acquisition. The Expert GIS RCWP system recommends one or more control systems based on site-specific conditions that are either input directly by the user or calculated by customized GRASS 4.1 functions. The user always specifies the contaminant of interest and the season while a GRASS 4.1 function (r.hydro-grp) always determines the soil hydrologic group of each field. For the other factors (loading potential, leaching potential, and application class), however, the user has two alternative ways to decide the input values. For example, after the user selects a contaminant of interest, the program displays the contaminant loading potential window. If the user knows the potential level of the selected contaminant, it can be entered. Otherwise, the user can let the GRASS 4.1 functions derive loading potential from existing field data. The direct input option can also be used to help the user address WHAT-IF questions.

When the user selects the GIS functions to determine the loading potential, XGRCWP makes a series of calls to appropriate customized GRASS 4.1 functions according to the current contaminant of interest. For example, if the contaminant is total nitrogen, the functions "r.manure", "r.fert", and "r.b.concentration" are called to estimate total nitrogen from manure, fertilizer and soil base concentration, respectively. Another GRASS function, "r.np.loading" is then called to translate the quantitative measure of loading potential into the quantitative classification (low, medium, or high) as input to the

Expert GIS RCWP system. These GRASS 4.1 functions generate the inputs by searching and converting the data from INFORMIX 4.1 relational data tables that are associated with the GRASS 4.1 spatially reference data, such as field boundary and soil map.

Control System Recommendation. XGRCWP derives the expert recommendations for control systems in two ways: a batch mode for every field in a watershed and an interactive mode for a user-specified field.

The batch mode uses, an existing GRASS 4.1 function "r.infer" to create a raster data layer for each general practice category of control practice according to a set of rules prepared for that general category. For example, the raster data layer representing the conservation tillage recommendations (CT.rec) can be generated by running "r.infer" with the appropriate rule. The "CT.rec" category value is 1 at each point in the data layer where conservation tillage is recommended, 0 otherwise. The "r.infer" function is similarly called for other general practice categories. The resulting map layers can then be displayed or further analyzed by additional GRASS 4.1 functions. The batch mode provides the user the overall picture with a watershed-wide view of feasible control systems.

The interactive mode displays the field boundary map, and the user can specify any field of interest by clicking on it. Recommendations and site-specific conditions of the field are displayed on the right half of the screen. Recommended control practices are also displayed within a popup window for further examination and include specific practices within each general category, feasible control systems for NPS pollution control, and research data reported about the practices. The interactive mode is implemented through the integration of a Bourne shell script, SQL commands, a customized GRASS 4.1 function (r.rcwp.expert), and GRASS 4.1 display functions with the Motif GUI. Interactive mode is intended for detailed consideration of a specific farm.

Interface to GIS Functions

XGRCWP provides a GUI to most customized GRASS 4.1 functions and some existing GRASS 4.1 functions. This GUI is intended to shield the user from complex syntax so that he/she can focus on the subject matter. The GUI makes it easier for the user to perform routine operations such as estimating contaminant loading, identifying critical areas, calculating erosion and runoff, and other watershed analysis tasks. It also helps the user make full and effective use of all the custom and some existing GRASS 4.1 functions.

Links to Database and Other Models

Data Structure. The GRASS 4.1 functions used to generate inputs for the Expert GIS RCWP system uses the same soils and fields relational databases as the Water

Quality Model/GRASS Interface under development by the USDA-SCS (1993). XGRCWP and custom GRASS 4.1 functions were tested for the Sycamore Creek watershed, Ingham County, Michigan. In this data structure, spatial data (field boundaries, watershed boundaries, soil map unit boundaries, and elevation data) are saved as GRASS 4.1 raster data layers while attribute data (crop information, fertilizing schedule, soil information, etc.) are stored in INFORMIX 4.1 relational database tables. Each field or soil map unit is assigned a unique ID number that is also contained in the field attribute (INFORMIX 4.1) data. The linkage between the GRASS 4.1 raster map and the INFORMIX 4.1 data is accomplished with a GRASS 4.1 category label.

Links to Database. To allow the interactive examination of field data from GRASS 4.1 raster layers and the associated relational database tables, XGRCWP calls the custom function "d.what.field.sh", a Bourne shell script that dynamically links GRASS 4.1 raster layers and the INFORMIX 4.1 database tables. When the user clicks on a field, for example, this function extracts field specific information from INFORMIX 4.1 tables such as field information, fertilizer schedule, crop operation schedule, and soil information. The "d.what.field.sh" function then displays all related soils and fields information for the given field. It also marks the field boundary map to remind the user which fields he or she has examined.

Links to Reference Modules. At any stage of the selection, evaluation, siting, and design procedure for control practices, the user can consult reference modules that provide information, guidance, and data about contaminant properties, transport variables, and examples of applications from RCWP projects. As described earlier, four reference modules are available in the Macintosh version of the RCWP Expert system: Contaminants, Monitoring, Transport, and Case Studies. The Penn State investigators are currently converting these reference modules into HTML documents for a Mosaic browser so that they can be accessed from XGRCWP. Mosaic is a public domain, Internet-savy document browser, which is available for X Windows, Macintosh, and Microsoft windows.

All four modules use graphics to demonstrate design procedures and contaminant control processes. The Contaminant module provides information about 11 categories of contaminants cited in various RCWP projects and their impacts on surface and groundwater resources. The Monitoring module describes different aspects of water quality sampling and analysis systems. The Transport module describes contaminant pathways in surface and groundwater. The Case Studies module presents detailed examples from key RCWP projects, and the examples cover both practice selection and implementation aspects of control systems. The reference modules serve as a complementary component of XGRCWP.

Links to AGNPS. AGNPS (Young et al., 1987, 1989) is a distributed-parameter, storm-event-based model that estimates runoff, sedimentation, and nutrient loss in surface runoff within agricultural watersheds. The prototype version of the Water Quality Model/GRASS Interface by USDA-SCS (1993) generates an AGNPS input file for all the cells in a watershed conveniently from the spatial and relational soils and fields databases. This input file can then be used by the UNIX version of AGNPS. XGRCWP can call AGNPS directly from its X-Windows interface and convert standard AGNPS model outputs for all the cells in the watershed into GRASS raster format for display and analysis.

DISCUSSION

Based on available publications and documentation, this report describes STEWARD (previously called RCWP Expert), a non-GIS version of an Expert system and its GIS version XGSTEWARD (previously called XGRCWP). These Expert system versions are knowledge-based software systems, being developed at Penn State to assist watershed project teams in the selection, evaluation, and implementation of NPS pollution and water quality control practices in agricultural watersheds. These developers first customized, tested, and used the RCWP Expert on St. Albans Bay, a 50-square-mile predominantly (65%) agricultural watershed in Vermont. They also customized, tested, and used the XGRCWP on Sycamore Creek watershed in Michigan.

Developers of the STEWARD Expert system from Penn State proposed customizing the system on the Lake Pittsfield watershed in Illinois. However, the system is still under development and therefore was not ready or available for use by the Lake Pittsfied watershed project team. Several attempts were made to install the system at the ISWS and customize it for the Lake Pittsfield watershed. Michael Foster from Penn State, principal developer of STEWARD, visited and spent two days in May 1997 at the ISWS to install the system and demonstrate its use. The visit turned out to be a series of sessions on debugging the AGNPS-ARC/INFO model described in a companion report (Borah and Allan, 1998). A subsequent visit by Dave Lehning from Penn State in February 1998 also turned out to help fix the bugs and problems in the Avenue scripts of the newly revised ArcView-AGNPS model. STEWARD developers from Penn State did not customize STEWARD for the Lake Pittsfield watershed, or release and hand it over to the ISWS project team; and therefore, the Expert system was never applied and used in the investigation of the Lake Pittsfield watershed. In other words, the ISWS team had no access to the system.

The ISWS has records of numerous communications made during the project period with Penn State scientists to keep the proposed schedule on customizing STEWARD and making it available to the ISWS project team. A sample of such communications is presented in Appendix A. In this communication, ISWS project leader Robert Sinclair wrote to Dave Lehning of Penn State asking key questions about progress on STEWARD. Sinclair clearly pointed out Penn State team's lack of communication with the ISWS team about their STEWARD progress and losing one of their key scientists Mike Foster. In a response to this communication, Penn State scientist Paul Robillard wrote to Robert Sinclair on November 25, 1997, apologizing for the "lapse in communication" and outlining a (new) "current plan" to customize XG-STEWARD for the Lake Pittsfield watershed. Sinclair shared this letter with Scott Ristau of IEPA via telefax on December 11, 1997. This led to the visit of Lehning to ISWS in February 1998, and the visit was unsuccessful in making progress, as mentioned above.

Descriptions of the expert systems and sources of knowledge from the existing literature and the RCWP demonstration projects presented in this report provide useful information on NPS pollution control practices. The Lake Pittsfield watershed project teams could benefit from these informational and educational materials.

STEWARD is an organized collection of existing knowledge on NPS pollution and the available control practices for agricultural watersheds in the United States. NPS pollution problems and control practices are extremely site-specific, and they have long been known by scientists and engineers working in this field. STEWARD could be a useful tool in abating site-specific NPS pollution. The major challenge is to evaluate the site-specific control practices for which improved physically based models are necessary.

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APPENDIX A

Sample Communication between ISWS and Penn State Teams

Mr. Lehning,

A couple of days ago, Dr. Abi Akanbi informed me that Dr. Mike Foster has left Penn State over two months ago. I am disappointed we were not informed of this fact sooner by either Mike or Dr. Robillard. We have been trying to reach Mike at Penn State for quite sometime. I am surprised Dr. Robillard did not mention Mike's leaving when he saw Mr. Rick Mollahan in Washington in September. Valuable time has been lost. It is my understanding that you are taking up or continuing on the project where Mike left off. If that is correct, could you please bring me up to date on the following:

Has the bugs been fixed that we reported to Mike when he was here?

Are the XG-STEWARD menus for BMP selection and watershed calibration operational and ready for testing?

Is the STEWARD-AGNPS AML software fully functional?

When will a beta version of the software be ready to be tested at the Water Survey and the IEPA?

If there are tasks yet uncompleted, what is your timetable or mileposts for completing the work on the model so that it can be tested in Illinois?

Thank you.

Regards, Bob.

Robert A. Sinclair
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November 25, 1997

Mr. Robert A. Sinclair
Senior Professional Scientist
Illinois State Water Survey
2204 Griffith Drive
Champaign, Illinois 61820

Dear Bob,

Thank you for your recent communication. I apologize for the unfortunate delay. As you know the original document was sent to Mike Foster and was not to forwarded to me. We also assumed Mike had communicated with you before he left Penn State. To avoid any future delays, as we discussed recently, please direct all communication to me in the future.

We have recently reorganized our support functions at the AIWQ Center and I believe it will be much easier to interact with your development group. Our current plan includes the following:

12/9/97

1. Evaluation and technical assistance in installing and utilizing all GIS hardware and software for the purposes of utilizing XG-STEWARD and other AIWQ NPS watershed software tools.

2. Programming customization of XG-STEWARD to facilitate selection, evaluation and siting of NPS control systems for Lake Pittsfield.

3. Develop support functions which allow our AIWQ team to be involved in the design, problem solving, and training of an NPS Lake Pittsfield watershed project team.

In addition, we would like to make Lake Pittsfield a model watershed application not only for XG-STEWARD but other tools we have developed, including:

- NPS model interfaces
- methods for TMDL calculations
- wellhead protection criteria
- drinking water database and information systems
- water quality monitoring network design methods and software

As we work to implement and utilize these tools we should consider a workshop next spring or early summer. In addition, we would like to work with you on the development of a summary document describing the Lake Pittsfield project and the use of XG-

STEWARD and other analytical tools for watershed assessment and implementation efforts.

Bob, I'll call next week to arrange for a meeting so we can resume project activities. Again sorry for the lapse in communication. We are very much looking forward to working with your group.

Sincerely,

Paul

Paul D. Robillard
Associate Professor
Water Resources Engineering

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LOCATION: Illinois Environmental Protection Agency

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FROM: Bob Sinclair

Date: 12/11/97

TOTAL NUMBER OF PAGES INCLUDING COVER PAGE: 4

COMMENTS:

Scott,

The letter is dated Nov. 25th; it was postmarked the 29th, and I found it in my mail box on the Dec. 9th. I have forwarded it to Abi. I have not received any phone calls or messages from Paul.

Thank you.

Regards, Bob.

If you do not receive all the pages indicated, please call back as soon as possible

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