Institute of Water Research

Annual Technical Report

FY 1998

Introduction

Research Program

Abstract

During the 1998 program year, the Michigan Institute of Water Research (IWR) continued its activities and research program on the development of environmental information systems for environmental decision making; and on land use impacts and surface and groundwater contamination and protection, which are both top priority issues within the state. The IWR also initiated work on a watershed information system focusing on research, and extended education programs on watershed management and surface and ground water protection. One project entitled "Decision Support System for Natural Resource Planning" (02) was funded to address these problems and issues. In addition, support for the Institute of Water Research Information Dissemination, Retrieval, and Reference Service Program (22) was continued.

Descriptors: agriculture, aquifer characteristics, conferences, data analysis, data storage and retrieval, denitrification, environmental information system, fertilizers, geographic information systems (GIS), groundwater hydrology, groundwater modeling, groundwater movement, groundwater quality, groundwater recharge, herbicides, hydrogeology, information dissemination, information transfer, lakes, land use, land-water interactions, Michigan, microcomputer, nitrogen, nonpoint source pollution, pesticides, pollutants, pollution control, ponds, research, retrieval, regional watershed analysis, septic tanks, soil metabolites, systems analysis, technology transfer, urban water systems, water quality, water quality management, watershed management, wetlands

Water Problems and Issues

Introduction

Michigan has a very abundant and diverse supply of freshwater due, in part, to its unique geographical location within the Upper Great Lakes Region. Michigan is surrounded by four of the five Great Lakes, and contains 11,000 inland lakes greater than 5 acres in size. Water flows through 36,000 miles of river channel, and Michigan possesses a vast groundwater supply. These waters provide a wealth of resources for the diverse agricultural, industrial, and recreational opportunities of the state. However, the ever growing number of activities in the state continually add stress to this resource and can lead to further degradation of water. Because almost all of Michigan's waterborne wastes drain to the Great Lakes where the impact is accentuated due to the slow flushing rate of the system, water resource problems are largely concerned with water quality issues. In some specific areas, however, water quantity concerns relative to agriculture, minimum stream flows, and drought conditions can be of major importance also. Many of these water quality and water quantity problems are shared by other states in the

Great Lakes region and the nation. Within Michigan, water quality problems commonly are divided between the Great Lakes and inland waters and are often related. Groundwater contamination is also becoming increasingly prevalent in local areas, particularly in the southwestern part of the state where land use impacts are high, and sandy type soils exist.

Pollution Sources

Two of the most critical environmental problems presently facing the state of Michigan are surface and ground water quality management and the absence of land use planning that considers resources and the integrity of the ecosystem. The long history of acute and chronic toxic substance contamination has had a significant impact on the state's water resources. Toxic chemical and nonpoint source pollution have the potential to affect the chemical, physical, and biological balance of the state's surface and/or groundwater adversely. These toxic chemicals may be translocated into all parts of the atmospheric, terrestrial, and aquatic ecosystems. They also bioaccumulate in organisms, especially in the aquatic ecosystem. The widespread use and careless handling of toxic materials are even more critical than the nutrient enrichment problems because they pose a threat not only to human health but also to all other forms of life, both terrestrial and aquatic.

Excessive nutrients, primarily from non-point source pollution, accelerate the eutrophication process and can lead to an aesthetically undesirable aquatic environment. The 1972 Michigan ban on phosphorus in detergents coupled with mandatory removal of phosphorus from municipal wastewaters has substantially reduced the phosphorus loading to the surface waters of the state. In addition, upgrading the municipal wastewater treatment plants throughout the state has markedly reduced BOD loadings to the rivers. Despite these gains, inland streams and lakes are receiving continued, albeit reduced, nutrient enrichment primarily from nonpoint sources.

The contamination of Michigan's lakes and streams reached significant proportions in the late 1960s and early 1970s. Subsequently, public concern was raised over the pervasiveness of these substances and their potential capability to affect the environment adversely. Consequently, state and federal legislation was enacted to control these materials. Since then, most industrial discharges have been greatly reduced, and some have been eliminated. As a result of these reductions, today's most serious environmental problems are leaking underground storage tanks and improper disposal of toxic and hazardous chemical wastes and the leachate from old, abandoned landfill disposal sites, especially those near rivers, streams, and lakes. Over 3000 hazardous chemical contamination sites have been identified by the Michigan Department of Natural Resources. Additionally, over 300 Michigan landfills are sources of contaminated groundwater. They raise the prospect of major toxic substance problems as they contaminate land as well as ground and surface waters for years to come.

In 1992, Michigan's Relative Risk Analysis Project identified the absence of land use planning as the most critical problem facing Michigan. Land use and water resources are unequivocally linked. Almost every water quality problem can be traced back or associated with a particular land use activity. The type of land and the intensity of its use will have a strong influence on the receiving water resource. Whether the source is natural or comes from a human activity, the impact of any land use practice on either the quantity or quality of water can be substantial. In general, the water quality across the United States and in Michigan has improved over the last 20 years. The combination of regulations, best management practices, and a renewed stewardship ethic has been helpful in controlling many problems that had previously resulted in a decline in water quality or a decrease in water availability. However, an increasing population, developmental pressures, absence of land use planning, and competition for water resources, continually contribute to the degradation of water resources. Managing water resources on a watershed basis will help address potential impacts.

Groundwater

Whereas most of Michigan's groundwater resources are of sufficiently high quality for domestic use, the Michigan Department of Natural Resources has identified over 50,000 sites of known, suspected, or potential groundwater contamination. Of the more than 9000 sites with environmental contamination listed as a result of a survey mandated by the Michigan Environmental Response Act (Public Act 451, Part 201, formerly PA 307), 96 percent were expected or known to have adverse effects on water quality. Of these sites 56 have been targeted for clean up under the federal Superfund program. The glacial definition of Michigan's soils, the abundant groundwater deposits, and over 100 years of disposing of municipal and increasingly complex industrial wastes have combined to challenge the groundwater quality. Unlike surface water, groundwater, once contaminated, has no known natural processes available to detoxify it. Thus, the costs to evaluate the magnitude of this problem and then treat groundwater contamination are staggering.

Nitrate is one type of contamination that has been identified in many areas of the state. Nitrates easily infiltrate the soil, enter groundwater aquifers, and contaminate wells. Because they are relatively easy and inexpensive to detect, nitrates are currently being used as indicators to identify areas where more toxic compounds such as pesticides may have entered the groundwater.

Throughout agricultural areas of the Midwest, agricultural herbicides, a persistent and relatively mobile group of pesticides, have been detected in groundwater. Studies of drinking water wells in high risk areas of southwestern Michigan have detected the herbicide atrazine. Most concentrations were very low, indicating non-point source contamination, and probably occurred in pulses following application. The Michigan Department of Agriculture sampled groundwater at agri-chemical handling facilities and found herbicides (primarily atrazine) detectable at several of these sites. Studies with lysimeters in corn growing areas have shown varying amounts of atrazine and nitrate leaching from the root zone under various irrigation management strategies. Research and education are needed to reduce the dependency on chemicals in agriculture and to reduce losses of pesticides and fertilizers from farm fields.

Inland Surface Waters

The problems affecting surface water quality are diverse, with major causes being nonpoint source pollution, in-place toxic materials, combined sewer overflows, industrial and municipal wastewater discharges, and the discharge of contaminated groundwater into surface waters. Recent studies showed that the problem of toxic substances is even larger and more complex than had previously been envisioned. For example, diffuse atmospheric inputs may be responsible for up to 40 percent of the loading of pollutants such as PCBs and toxaphene into the Great Lakes and the inland surface waters of Michigan. The full scope of the toxic substance problem and its threat to human health and the environment has not yet been fully defined, and more effective controls to limit or eliminate these chemicals in the environment are critically needed.

Recent Midwestern studies by the U.S. Geological Survey (USGS) have shown widespread contamination of surface waters by atrazine, and other studies have identified several agricultural chemicals (primarily herbicides) in rivers used as drinking water sources in northeastern Ohio. In the USGS study, over 50 percent of 150 sites

showed detectable atrazine before spring field applications, and over 90 percent of those sites had detectable atrazine after field applications. Studies indicating impacts of pesticides on non-target, off-site organisms offer compelling evidence to support recommendations of reduced use and better management of these pesticides.

The Upper Peninsula has fewer and less intensive water quality problems than the other parts of the state primarily because of the sparse population and limited industry. The few problems center around urban areas scattered along the Lake Superior shoreline, tributary streams, and inland lakes. The major causes of the water quality problems are domestic and industrial pollution. Much less is contributed by nonpoint runoff from agricultural lands, urban runoff, and natural erosion.

Industries that contribute to the water pollution problems in the Upper Peninsula are primarily concentrated in the cities of Munising, Houghton, Hancock, and Marquette. Pulp mills, copper and iron mining companies, paper manufacturers, and power companies as well as small manufacturing firms are located in these and smaller municipalities. In addition to large discharges of heated water from electric power generating plants, these industries are responsible for the addition of coliform organisms, suspended matter, trace metals, oxygen consuming substances, and nutrients as well as phenols and other toxic materials discharged into Lake Superior and its tributary waters.

As in the Upper Peninsula, the vast majority of the streams in the northern portion of the Lower Peninsula have good to very good water quality. While water quality problems have not yet reached serious proportions in the southern portion of the Lower Peninsula, they are more acute than further north due to the greater industrial, municipal, and agricultural activities. Seven stream segments representing less than one half of one percent of the state's streams were designated by the Michigan Department of Natural Resources as having poor water quality due to the bioaccumulation of toxic materials in fish. In several areas of Michigan, fish consumption advisories are currently in effect.

The Great Lakes

Much of the national and international attention to water quality in Michigan is focused on the Great Lakes. The Michigan Department of Natural Resources, the International Joint Commission, the Michigan Sea Grant College Program, and others have noted that Lake Superior, Northern Lakes Huron and Michigan are oligotrophic. Southern Lake Michigan is oligomesotrophic; southern Lake Huron and central Lake Saint Clair are mesotrophic, and the Saginaw Bay, western Lake Saint Clair and Lake Erie are eutrophic. The eutrophic areas of the Great Lakes, all associated with basins of high population density, indicate the relationship between human activity and water quality. The solutions to many of the problems of the Great Lakes lie inland, within the state. Consequently, by protecting the water quality of the inland lakes and streams, the Great Lakes can also be protected.

In many near shore areas of the Great Lakes, sediments, water and fish exhibit unacceptably high concentrations of heavy metals and toxic organic substances because of urban and agricultural runoff as well as other discharges, both intentional and unintentional. Specifically, the FDA action levels for PCB and dieldrin are often exceeded in predator and forage fish taken from many of the near shore areas of the Great Lakes. However, fish are the only food group in which detectable levels of PCB are routinely found.

One serious problem was the discovery of widespread mercury contamination of fish in many of the inland lakes. Despite decreases in domestic, industrial and agricultural uses and point source releases of mercury into the environment over the last two decades, relatively large quantities are still emitted by coal fired power plants,

nonferrous smelters, and refuse incinerators. Unlike other heavy metals that are usually associated with particulates and fall to the ground within a short distance of their emission point, mercury does not because it is readily vaporized. Thus, additions from anthropogenic sources to those from natural processes continue the geochemical cycling of significant quantities of this highly volatile, toxic trace metal through the environment. Atmospheric transport is the major route for global deposition to aquatic and terrestrial ecosystems even in areas remote from where it was originally released. As a result, the Michigan Department of Public Health issued an advisory warning individuals, especially young children and pregnant women, to limit their consumption of fish from Michigan's inland lakes.

Direct industrial sources of contaminants can more easily be pinpointed than the more diffuse airborne sources that also contribute a number of toxic organic compounds such as chlorinated aliphatic, aromatic and polyaromatic hydrocarbons. These are bioaccumulated by aquatic organisms; however, the full ecological impact is very difficult to determine and is unknown at this time. Moreover, while the known compounds were being studied, a number of additional organic compounds such as haloforms, bromoforms, chlorinated phenols, chlorinated hydrocarbons, mirex, dioxins, dieldrin, furans and aldrin were identified as potential problems in the Great Lakes. One of the serious toxic organic contamination problems from a point source has been identified at White Lake adjacent to Lake Michigan where chlorinated hydrocarbons such as carbon tetrachloride, tetrachloroethylene, and hexachlorocyclopentadine are seeping from a buried waste disposal site. The leachate from this site has increased the levels of a number of toxic chemicals in the water, fish, and sediments in White Lake. In contrast, the 1969 ban on DDT effectively reduced this compound in the fish and a commensurate decrease in PCB levels has also been recorded in fish since its ban in 1977.

The International Joint Commission (IJC), a United States-Canadian commission created by the Boundary Waters Treaty of 1909, monitors the water quality of the Great Lakes under the terms of the Great Lakes Water Quality Agreements of 1972 and 1978. These international agreements foster intergovernmental cooperation to solve pollution problems. Based on state and provincial recommendations, the IJC has currently designated 43 Areas of Concern where environmental quality is degraded and beneficial uses of the water and biological communities are adversely affected. Each state or province is responsible for the preparation of remedial action plans for the Areas of Concern within its borders. Michigan is drafting such plans for the 11 Areas of Concern for which it is solely responsible and participates in three additional Areas of Concern where it shares this responsibility with a neighboring government. Problems in the Areas of Concern include: heavy metals, toxic organic substances, and conventional pollutants.

Solutions

As water resources are used and degraded, sound economic evaluations must be performed to develop institutional rules to govern them. The Michigan Great Lakes and Water Resources Planning Commission developed an economic/institutional analysis to manage the water resources of the state effectively with the purpose of maintaining water availability and quality adequate to meet the present and future requirements of all the users in the state. The Office of Water Resources, within the Michigan Department of Natural Resources, has since been formed to implement the recommendations made by the Commission.

A complicating factor is that Michigan does not remain in a static situation in relation to the water problems of other states. As the major aquifers in the plains states continue depletion, economic forces may increase the need for agricultural water in Michigan to the point where its use as a clean resource will be threatened. Research conducted in irrigation, chemigation, conservation tillage, and other agricultural uses can establish sound

procedures to prevent or minimize degradation. Modeling and analyses will improve the predictability of location, rate, and amount of surface runoff, infiltration, and evapotranspiration. These will further facilitate proactive measures against waterborne contaminants and subsequent degradation of groundwater.

While efforts must continue to establish research in these areas, base-line monitoring must also continue. As Michigan puts higher value on its freshwater resources, the Michigan Institute of Water Research program is prepared to participate more actively in the research and information dissemination opportunities at hand.

Program Goals and Priorities

Due to reduced funding, only one research project in the Institute of Water Research's 1998 program was selected to address those priorities which constitute major problems not only with respect to Michigan's water resources but also regional and national water resource concerns. The goal of this project is to develop methods to deal with and integrate the vast amount of data being generated in Michigan and the Great Lakes Basin. In the meanwhile the multitude of water quality management and pollution problems in Michigan continues. This will be accomplished through the development of an information exchange integrated support system for watershed studies which emphasizes on land use and natural resource stewardship. The system supports research, studies by faculty and graduate students in several department as well as planning and management by local, county, state, and federal agencies. The specific objectives of the project are to: 1) Integrate concepts and activities in watershed systems and extended education through a networking infrastructure of organizations and digital communication pathways with integrated distributed data sources and partners; 2) develop computer/network based Natural Resources Integrated Information System (NRIIS) with graphical interface and search mechanisms to access models, data, information, and GIS/graphic tools; and 3) to train graduate students to use the system to facilitate their research, see how their study is part of a larger system, and gain experience with NRIIS and its power for enhancing research, technology, and information transfer and communication for informed natural resource policy, planning, and management decisions.

While they cannot all be resolved, selected research priorities have been identified in the Five-Year Water Research and Development Plan. The 1998 Institute of Water Research program focused its information dissemination and retrieval efforts in the following major areas:

- Definition of the mechanisms affecting the fate, transport, and effect of toxic/hazardous materials which enter the surface and groundwater as waste products or pollutants.

- Investigation of physical, chemical, and biological variables controlling groundwater quality and quantity.

- Investigation of mechanisms that influence non-point source pollutants, including urban and agricultural land runoff, residual waste disposal, on-site sewage disposal systems, atmospheric deposition, and water conservation through irrigation scheduling.

- Identification of control mechanisms affecting lake eutrophication and the development of management strategies to minimize the impact on inland lakes and the Great Lakes.

The Research Project

One research project was funded with the fiscal dollars allotted. With a growing need in the Water Research Institutes in the Great Lakes region to develop new methods for collecting, integrating, and disseminating information and data concerning the priority areas identified previously, the study by Bartholic (02) entitled "Decision Support System for Natural Resource Planning" presented a method for enhancing understanding of water related issues such as groundwater contamination and land use impacts on water quality, and how geographic information systems can be utilized in addressing these issues. The objective of the project was to couple new information technologies with broad data and information to enhance the use and transfer of information to facilitate better local decision making, and to provide a watershed information system for research and extended education programs focusing on watershed management and surface and ground water protection.

Basic Project Information

Basic Project Information	
Category	**Data**
Title	Decision Support System for Natural Resource Planning
Project Number	96-G2026-02
Start Date	03/01/1997
End Date	02/28/1998
Research Category	Biological Sciences
Focus Category #1	Management and Planning
Focus Category #2	Water Quality
Focus Category #3	Models
Lead Institution	Michigan State University

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Jon F. Bartholic	Professor	Michigan State University	01

Problem and Research Objectives

An information exchange integrated support system for watershed studies with emphasis on land use and natural resource stewardship was developed. The system supports research, studies by faculty and graduate students in several departments as well as planning and management by local, county, state, and federal agencies. The specific objectives of the project are to:

1. Integrate concepts and activities in watershed systems and extended education through a networking infrastructure of organizations and digital communication pathways with integrated distributed data sources and partners.
2. Develop computer/network based Natural Resources Integrated Information System (NRIIS) with graphical interface and search mechanism to access models, data, information, and GIS/graphic tools; and

3. to train graduate students to use the system to a) facilitate their research, b) see how their study is part of a larger system, and c) gain experience with NRIIS and its power for enhancing research, technology, and information transfer and communication for informed natural resource policy, planning, and management decisions.

Methodology

Data and information pertaining to water resources, landuse/cover, and applications of GIS was located and researched. This has been accomplished by working with local professionals, practitioners, consultants, and in educating local decision makers about watershed functions and related policy options for the facilitation of water quality protection. Information on background, functions and use of GIS were obtained and summarized using text and graphics. Modules focusing on Geographic Information Systems and Statewide Data were developed in an interactive format utilizing hypertext markup language and the World Wide Web. The extensive use of extended education over the internet using hypertext techniques greatly facilitated the effectiveness of wide dissemination throughout the state and region relative to watershed education and applicable policies. Further, many of these modules and approaches can be used nation-wide

Principal Findings and Significance

Enhancing the use and dissemination of data and information to various user groups is one method for assisting user groups in their decision making process. Although data is extensively available, it is often in a format that is not easily accessible or difficult to comprehend. By processing the data into map format and making it easy to access, users can quickly identify their areas of concern and get a better idea as to the problems that may be associated with the issue they are addressing. The use of the internet is a mode of distribution that is growing exponentially. The development of an educational module that provides descriptive information, processed data, and related graphics, along with hypertext links to other sources of information has proven to be a viable means of transferring information to a wide audience. IWR is currently working cooperatively on an eight state region-wide project which will ultimately allow users/decision makers, etc. access to this vital data.

Descriptors

Data Analysis, Data Storage and Retrieval, Geographic Information Systems (GIS), Information Dissemination, Systems Analysis, Water Quality Management, Watershed Management

Articles in Refereed Scientific Journals

One module is accessible on the WWW through the Institute of Water Research's home page. The address is: http://www.iwr.msu.edu/edmodule/ilmfrm1.htm

The activities on which this report is based were funded in part by the U.S. Geological Survey, through the Institute of Water Research, Michigan State University.

Book Chapters

NA

Dissertations

NA

Water Resources Research Institute Reports

NA

Conference Proceedings

NA

Other Publications

NA

Information Transfer Program

Information Dissemination, Retrieval, and Reference Program

Project Relevance

Michigan's water supply is abundant and widespread due in large part to Michigan's geographical location within the Upper Great Lakes Region. Michigan is surrounded by four of the five Great Lakes, and contains 11,000 inland lakes greater than 5 acres in size. Water flows through over 32,000 miles of river channel, and Michigan possesses a vast groundwater supply. These waters provide a wealth of resources for the diverse agricultural, industrial, and recreational opportunities of the state. However, the ever growing number of activities in the state continually add stress to this resource and can lead to further degradation of water. Because almost all wastes drain to the Great Lakes where the impact is accentuated due to the slow flushing rate of the system, water resource problems in the state are largely concerned with water quality issues.

As land use impacts that degrade water quality become more widespread, the need for action at the watershed level becomes more apparent. The movement of pollutants across a watershed is not constrained by political boundaries, and activities in one political jurisdiction may lead to water degradation in another. The difficulty in assessing impacts from erosion, nonpoint source pollution or shoreline development lies not only in the magnitude of the data collection efforts, but in the proper analysis and interpretation of the data needed for assessing the problem.

In order to stay informed of water quality changes over time, and to determine if efforts being made to reduce pollutants are proving effective, an education and monitoring program is appropriate. An effective information dissemination and training program facilitates the transfer of information needed to protect the water resources in the state, and helps to inform scientists, legislators, and citizens of the most recent information available. For further effectiveness, agency personnel, riparians, educators and others interested in protecting their water resources or in teaching others about it must understand the importance of collecting and/or analyzing information

at the watershed level to ensure that reliable and appropriate information is being used to make sound decisions for water quality protection.

Project Objectives

The Institute of Water Research has a long history of providing effective information dissemination and training programs. These programs have involved close cooperation with other groups and organizations within the University and the state in order to enhance their effectiveness. Because educational levels and prior knowledge in the subject area are so varied, a number of transfer mechanisms are necessary. These range from the direct dissemination of brochures, pamphlets, and technical and nontechnical books to computer models, the publication of technical completion reports, and videos, conference and seminars for both lay audiences and professional groups throughout the state. Training sessions on water-related topics, such as lake eutrophication, nonpoint source pollution, and stream monitoring, provide hands-on experience for a number of diverse audiences.

The following objectives relate to information dissemination programs arising from water-related activities at the Institute of Water Research.

1. Develop and present educational programs such as conferences, seminars, and training workshops designed to increase the public's awareness and appreciation of the water quality problems in the state and to stress the economic trade-offs required to solve any problem.

2. Review, edit, and publish water conferences and workshop proceedings.

3. Prepare lecture/demonstrations and audio-visual materials for presentations to college classes, secondary and elementary schools, and private groups on such topics as watershed management, wastewater treatment, wetland and lake ecology, water conservation, and groundwater contamination.

4. Utilize the dissemination potential of the worldwide web by developing educational modules; interactive models; and virtual reality courses.

5. Cooperate with the Michigan State University Extension to make water-related information available through the county cooperative extension agents.

Description of Projects Implemented in FY 1998

The Institute of Water Research Technology Transfer and Information Dissemination Program began in the early 1970s, and has been expanded and improved to be more responsive to the informational needs of a wide variety of user groups. In order to promote the maximum exchange of information, the combination conference/workshop format has often been selected as the most versatile for scientific/researcher oriented groups. These conferences are open to public participation and present new and current information, often providing recommendations for future research and outreach.

Lectures, Conferences, and Workshops

Conferences

Four conferences/workshops were held in FY 98 with the Institute as either sponsor or co-sponsor. The 9th annual Great Lakes conference, titled, The Great Lakes: Five Decades of Change was held in March. The one-day conference provided an overview of the tremendous changes in the Great Lakes that have occurred during the past half century and presented information on their current status. The four theme areas for the conference were: 1) Species introductions and invasions; 2) Water quality issues such as contamination of fish by toxic substances and the direct implications to human health of eating these fish; 3) Great Lakes Management; and 4) Restoration issues. A total of 125 people attended. The Institute also co-sponsored a conference in March on Watershed and Aquatic Plant Management with the Michigan Chapter, North American Lake Management Society. Issues concerning boating, exotic species, aquatic plants, and health were presented. Approximately 35 people attended.

In August, the Institute's water quality coordinator assisted with the development and instruction of a two day workshop on Protecting Inland Lakes, Part I. This intensive training session was aimed at riparians and lake association personnel. The workshop consisted of general information on lakes and provided hands-on experience for testing lake water, collecting data, and interpreting results. The class was limited to 30 people and was filled to capacity.

The Institute also sponsored and coordinated the 2nd Annual Michigan Groundwater Protection Conference: Building Partnerships for Drinking Water Protection in October. Topics included:

Land Use Techniques for Water Resources Protection; Conducting a Contaminant Source Inventory; Groundwater Guardian Success Stories; Groundwater 101; Addressing Michigan's Abandoned Wells; Agriculture and Drinking Water Protection; Team Building and Contingency Planning for Wellhead Protection; and An Introduction to Global Positioning Systems. Concurrent sessions were held and a total of 120 people attended the two day event.

Wetlands Tracking System

The Institute worked with the Department of Environmental Quality (DEQ) to create a computerized Wetlands Tracking System (WTS). The pilot version of WTS provides a framework for assembling, accessing, analyzing, and linking external information to GIS data layers. This allows users to develop their own integrated information system, using any available data type or information source. Development of the pilot version focused on only one county; however, the WTS has been designed for expansion to state-wide coverage. The WTS was designed for flexibility, expandability, and ease-of-use, and is currently being used by district staff at one of the DEQ's surface water quality field offices.

Information on the Web

The Institute of Water Research (IWR), with funding provided by the MSU Extension Water Quality Committee, has developed a web-based program called the Water Quality Data Access System that allows a user to access a variety of water quality data by county or watershed and view summary information on the parameter(s) of interest as well as the location where the sample was originally taken. The data was obtained from STORET, but only Michigan data was downloaded and of the hundreds of variables available, only a limited number have been summarized.

The program enables the user to obtain environmental water quality data by either county or watershed. The user can also access a map which includes the sampling stations where data was obtained, locations of rivers, intermittent streams, lakes, and the county or watershed boundary. The web address for this site is: http://www.gis.iwr.msu.edu/storet. As Water Quality Coordinators for MSU Extension, Institute staff assembled an Expert's Directory on the web for Extension personnel. The Directory highlights faculty and specialist at MSU

who are doing research, outreach and/or extension activities in water related areas. Each listing includes the person's area of expertise, publications, outreach materials, classes taught, and contact information.

Demonstrations and Exhibits

The Institute took part in the Michigan Science Olympiad by serving as the State Supervisor for Water Quality in the state finals. This annual event attracts nearly 100 junior high and high schools across the state who compete in a variety of science related events. Winners of the event continued to the national finals.

Another national high school event, the Michigan ENVIROTHON was also held at MSU, and one of the Institute staff served as the co-leader of the event. This event brought in hundreds of students to compete in science related events.

In late July, MSU's Ag Expo, an agricultural oriented exposition is held. Approximately 35,000 people attend this annual event. Each year the Institute features an educational exhibit. In FY 98, the Institute focused on land use and water quality. Coordinating efforts with the Michigan Groundwater Stewardship Program (MSGP), the Institute demonstrated the effects of various land use practices on both surface water and groundwater while the MGSP performed water testing analyses for atrazine and nitrate.

Lectures, Workshops, and Training

The Institute staff gave numerous presentations throughout the year on issues such as wetland functions; wellhead protection, water quality management for golf course superintendents, household hazardous wastes, indicator species for water quality testing, and nonpoint source pollution. Audience participation ranged from approximately 25 to over 100 for each presentation.

Institute personnel also coordinated efforts with Extension and the Kellogg Biological Station in developing a workshop on Protecting Inland Lakes. The first part of the two part intensive training dealt with basic lake concepts, and provided hands-on training for participants. An Institute staff member assisted with the development of the manual, and served as one of the instructors during the hands-on training portion.

Personnel and Facilities

The Institute of Water Research maintains such facilities and equipment as the latest software packages for desktop publishing, GIS, video editing and photographic equipment to support its Information Dissemination Program. It also has microcomputers, three Sun Sparc-20 work stations, a graphic plotter, scanner, color printer, and digital camera to enhance its educational programs. For field demonstrations and research related opportunities the Institute also has a Data Sonde mini-probe for measuring chemical parameters in lakes.

In addition, the Institute of Water Research operates the Inland Lakes Research and Study Center (ILRSC) at Michigan State University. Located four miles south of the main campus, the ILRSC consists of a 200 acre fenced site with four manmade, shallow enriched lakes that average six feet in depth and total 40 surface acres. Additionally three artificial one-acre marshes are located at the ILRSC. They are tiered to a depth of three feet, lined with two feet of native clay, and have a typical complex of marsh vegetation. The four lakes and three marshes provide a diverse array of aquatic habitats and an opportunity for whole lake studies and demonstrations. The 160 acres surrounding the lakes can be utilized for terrestrial studies.

The conference/workshop facilities of the Center include an indoor demonstration/lecture room. Concrete boat launching ramps provide convenient access to each lake. The ILRSC is open for tours and workshops from April

through October. Elementary, high school and college classes continually take advantage of the outdoor facility by holding classes there. IWR staff hold combination lectures and workshops, and cover a variety of water related topics.

The Institute's technology transfer program is under the direction of Principal Investigators Dr. Lois G. Wolfson, with several Institute personnel contributing to the project, including Dr. Frank D'Itri, Ruth Kline-Robach, Elaine Brown, and Joseph Ervin.

Groundwater Education in Michigan Program (GEM)

The Groundwater Education in Michigan (GEM) program completed its eleventh year of operation at the Institute in January of 1999. The GEM program was developed by the W.K. Kellogg Foundation (WKKF) in cooperation with the Institute. GEM is a comprehensive effort to encourage communities to develop local action-oriented groundwater protection projects. An extended three year $597,000 grant completed its third year of institutionalizing the GEM program. The funds were used to implement comprehensive groundwater protection, to increase local awareness of the groundwater resource, and to initiate ongoing groundwater education outreach programs.

In Spring of 1998, GEM projects and materials were highlighted during groundwater protection presentations to all grantees of Michigan's Groundwater and Freshwater Protection Act Program (PA 247). The GEM program has been honored for its pioneering drinking water awareness efforts.

Inland Lakes Research and Study Center Classes and Demonstrations

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Conferences and Workshops

1. Land Treatment of Municipal Wastewater: Vegetation Selection and Management Conference (February 1981)
2. Municipal Wastewater in Agriculture Conference
3. Acid Precipitation: Effects on Ecological Systems Conference (March 1981)
4. Competition for Water in Michigan Conference (April 1981)
5. Lake Eutrophication: Causes, Effects, and Remedies Workshop (October 1981)
6. Contamination of Groundwater Supplies by Toxic Chemicals Workshop
7. Aquatic Plant Control Summer Workshop (June 1982)
8. Do-It-Yourself Water Chemistry Summer Workshop (July 1982)
9. Inland Lake Fish Management Summer Workshop (July 1982)
10. Nutrient Control and Wetland Values Summer Workshop (August 1982)
11. Farm Pond Improvements Workshop (March 1983)
12. The Impact of Farming Practices on Fish, Wildlife, and Water Quality Conference (March 1983)
13. Waste Treatment Alternative for Rural Communities Workshop (May 1983)
14. The 1983 Annual Conference of the National Association of Environmental Professionals on Environment and Economics (co-sponsor)(April 1983)
15. Artificial Reefs in the Great Lakes Conference (June 1983)
16. Inland Lakes Research and Study Center Summer Conference Series II (4 one-day conference/workshops, June and July 1983)
17. Ag Expo Educational Exhibit (July 1983-1992)
18. Water Use in Agriculture Conference (August 1983)
19. Environmental Education: Aquatic Ecology Workshop (August 1983)
20. A Systems Approach to Conservation Tillage Conference (February 1984)
21. Michigan's Inland Water: Current Demands, Future Conflicts Conference (March 1984)
22. Farm Pond Construction and Maintenance Conference (March 1984)
23. Our Great Lakes: Resources for Growth with Quality (March 1984)
24. Four-H Exploration Days Water Quality Workshop (June 1984-1989)
25. Food Chain Dynamics in Recreational Lakes Workshop (July 1984)
26. Michigan County Commissioners: Workshop on Groundwater Contamination (July 1984)
27. Health Hazards in Surface and Groundwater Conference (August 1984)
28. Statewide Water Planning Session (September 1984)
29. Water and Land Resource Analysis System Demonstration (October 1984)
30. Great Lakes Coastal Wetland Colloquium (November 1984)
31. Recreational Potential and Management of Small Ponds (March 1985)
32. Water Use Issues in Michigan (March 1985)
33. The Hands-On Approach to Lake Management (August, September 1985)
34. Technology Transfer Exchange Forum for Communication Specialist (October 1985)
35. Small Pond Management and Fee-Fishing Potential (March 1986)
36. The Hydrogeological Cycle and Water Conservation (July 1986)
37. Workshops on Water Quality and Management at the ILRSC (September 1986)
38. Rural Groundwater Contamination: Assessment of Needs, Strategies for Action (October 1986)
39. Groundwater Protection: Economics, Health and the Environment (March 1987)
40. FOCUS: Conference on Midwestern Groundwater Issues (Co-sponsor) (April 1987)
41. Improving Local Environmental Decision Making: Development and Application of Spatial Information Management Systems (June 1987)
42. Michigan's Future On-Line: Geographic Information Systems and You (March 1988)
43. Local Action Strategies for Groundwater Protection (May 1988)
44. Conference/Workshop on the Status of Knowledge, Critical Research Needs, Legislation and Development

of Appropriate Technology for The Michigan Groundwater Quality Challenge (November 1988)
45. Governor's Conference on Water in Michigan: Into the Next Century (March 1989)
46. The Midwest Groundwater Quality Protection Challenge (November 1989)
47. Promoting Sustainability in Michigan Agriculture (March 1990)
48. International Perspectives on Great Lakes Resource Management Issues (March 1990)
49. Assessing Agricultural Impacts on Groundwater Quality (March 1990)
50. Protection and Management of High Quality Lakes (Co-sponsor, June 1990)
51. Wetlands Management Strategy Workshop (Co-sponsor, November 1990)
52. Wetlands Management Strategy Conference (Co-sponsor, December 1990)
53. Great Lakes Fisheries: A Resource Under Stress (March 1991)
54. Rediscovering the Grand River: Findings of Expedition '90 (March 1991)
55. Alternative Deicing Technologies and the Environment (March 1991)
56. Saginaw Bay Water Quality Workshop (July 1991)
57. Water Quality Research Progress/Evaluation Meeting (July 1991)
58. Emerging Issues and Concerns in the Great Lakes (March 1992)
59. Current and Emerging Trends in Environmental Education (March 1992)
60. Grand River Extravaganza (April 1992)
61. Great Lakes Region Groundwater Education Summit (Co-Sponsor, May 1992.
62. Site Specific Crop Management: Emerging Technologies for Efficient and Economical Agricultural Production (Co-Sponsor, August 1992).
63. Great Lakes Expectations: Managing for the Future (March 1993)
64. Building and Using Wetlands (March 1993)
65. Jurisdictional Delineation of Wetlands in Michigan (August 1993)
66. National Groundwater Education Consortium (October 1993)
67. Annual Groundwater Networking Conference (November 1993)
68. Rehabilitating the Great Lakes: Back to the Future (March 1994)
69. Agricultural Summit I: An Assessment of Future Trends for Pesticide use in Michigan (February, 1994).
70. Showcasing Success: Groundwater Education Strategies that Work (March 1994)
71. Protecting Groundwater: Promoting Understanding, Accepting Responsibility and Taking Action (December, 1994).
72. Great Lakes Expectations: Attaining 20/20 Vision (March 1995)
73. GEM Networking Conference (October 1995)
74. Water Quality Monitoring and Interpretation: A Watershed Approach (July 1995-co-sponsor)
75. Valuing the Great Lakes: Michigan's Investment for the Future (March 1997-sponsor)
76. Understanding and Using GIS (Geographic Information Systems) for Water Quality Decisions (April 1997-co-sponsor)
77. Water Quality Monitoring and Interpretation - Phase II (August 1997-co-sponsor)
78. New Technologies for Onsite and Small Community Wastewater Treatment Systems for Improving Water Quality (September 1997-co-sponsor)
79. Groundwater Networking Conference (November 1997-sponsor)
80. Drinking Water Celebration (May 1997-sponsor)
81. 4-H Exploration Days - Wet, Wild, Wonderful (Summer 1997)
82. Ag Expo-1996 - Land Use and Water Quality (July 1997)
83. Farm*A*Syst and Home*A*Syst Training (Spring 1997)
84. Net-21 Training (Spring 1997)
85. Ag Summit (Fall 1997)
86. Water Quality Training for Golf Course Superintendents (Spring 1997)
87. Michigan Water Festival (Summer 1997)
88. Ag Expo '97 - Land Use Effects on Drinking Water (June 1997)
89. Farm*A*Syst and Home*A*Syst Training (January 1997)

90. Inland Lake Management: Use or Abuse? (November 1997)
91. WINFO-X and Introductory Arc View Training (July 1997)
92. Michigan Section American Water Works Association (March 1997)
93. Michigan Water Environment Association (March 1997)
94. Watershed presentation at Southwest Michigan Watershed Management Short Course (March 1997)
95. Groundwater presentation at Golf Course Superintendent Training (March 1997)
96. Groundwater presentation at Allen Street School, Lansing, April 1997)
97. Michigan Association of Local Environmental Health Administrators (two board meetings)
98. 1997-98 National ENVIROTHON Competition
99. Second International Conference for the Protection of Aquifers in Queretaro, Mexico (May 1997)
100. Michigan Integrated Food and Farming Systems (MIFFs) Fourth Grade FarmFest (May 1997)
101. West Michigan Public Broadcasting station 30 minute groundwater panel session (June 1997)
102. American Water Resources/Universities Council on Water Resources Annual Conference (July 1997)
103. Drinking water protection presentations in four Michigan regions for county commissioners
104. First Annual Michigan Groundwater Protection Conference (November 1997)
105. Groundwater Guardian Conference (November 1997)

USGS Internship Program

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	2	N/A	N/A	N/A	N/A
Masters	4	N/A	N/A	N/A	N/A
Ph.D.	2	N/A	N/A	N/A	N/A
Post-Doc.	N/A	N/A	N/A	N/A	N/A
Total	8	N/A	N/A	N/A	N/A

Awards & Achievements

See Technology Transfer Section

Publications from Prior Projects

Articles in Refereed Scientific Journals

NA

Book Chapters

NA

Dissertations

NA

Water Resources Research Institute Reports

Bartholic, J.F., 1998. Michigan State University-Institute of Water Research, Spring 1998 Update Report. 2 pp.

Conference Proceedings

79. Ouyang, D., J. Bartholic, and E. Hesketh. 1998. Risk-based analysis of pesticide applications in agricultural croplands. In: The Proceedings of the Watershed Specialty Conference - Watershed Management: Moving from Theory to Implementation. May 3-6, 1998, Denver, CO. pp 1089-1096.

D'Itri, F.M. 1998. Environmental Contamination: An Anthology. International Training Workshop on Environmental and Occupational Health, U.S. National Institutes of Health and Bulgarian Ministry of Health, Velingrad, Bulgaria, 56 pp.

Other Publications

Publications

1. *Water Impacts (monthly newsletter: January 1980-1998)*
2. *Land Treatment of Municipal Wastewater: Vegetation Selection and Management (Ann Arbor Science Publishers, 1982, 219 pp.)*
3. *Municipal Wastewater in Agriculture (Academic Press, 1982, 492 pp.)*
4. *Acid Precipitation: Effects on Ecological Systems (Ann Arbor Science Publishers, 1982, 506 pp.)*
5. *PCBs: Human and Environmental Hazards (Ann Arbor Science Publishers, 1983, 443 pp.)*
6. *Impact Evaluation of Increased Water Use by Agriculture in Michigan (AES Research Report Number 449, Technical Information Series, 1983, 194 pp.)*
7. *Research and Extension Opportunities at the Inland Lakes Research and Study Center (Institute of Water Research publication)*
8. *Lake Management Fact Sheets: Greenbelts, Water Conservation, Water Chemistry, Dissolved Oxygen, pH, Chlorides, and Alkalinity (Institute of Water Research publication)*
9. *Michigan State University Water Resources Faculty Directory - 1982 (Institute of Water Research publication)*
10. *Great Lakes Experts Directory - 1983 (Institute of Water Research publication)*
11. *Institute of Water Research Programs Brochure*
12. *Water Quality and Aquatic Plant Control (pamphlet)*
13. *Michigan Water Connections - State Water Planning, 1985 (Institute of Water Research Publication*
14. *Artificial Reefs (Lewis Publishers, Inc., 1985, 589 pp.)*
15. *A Systems Approach to Conservation Tillage (Lewis Publishers, Inc., 1985, 384 pp.)*
16. *Coastal Wetlands (Lewis Publishers, Inc., 1985, 286 pp.)*
17. *Proceedings of The Interstate Information Exchange for Strategic Water Planning in Michigan. 1985 (Institute of Water Research publication)*
18. *Rural Groundwater Contamination (Lewis Publishers, Inc., 1987, 416 pp.)*
19. *An Introduction to Michigan's Water Resources (Institute of Water Research publication, 1987,*

64 pp.)

20. *Nitrate--A Drinking Water Concern (Extension Bulletin WQ 19, 1988)*
21. *UCOWR Expertise Directory (1988)*
22. *GEM NOTES (bimonthly newsletter)*
23. *Private Well Water Testing (December 1989)*
24. *The Status of Nitrate and Atrazine in Michigan Groundwater (July 1990)*
25. *The Saginaw Bay, Michigan Subirrigation Drainage Project 1987-1988 (November 1990)*
26. *A Guide to Home Water Treatment, CES Water Quality Series, Bulletin WQ 21 (1990)*
27. *Distillation for Home Water Treatment, CES Water Quality Series, Bulletin WQ 22 (1990)*
28. *Home Water Treatment Using Activated Carbon, CES Water Quality Series, Bulletin WQ 23 (1990)*
29. *Reverse Osmosis for Home Water Treatment, CES Water Quality Series, Bulletin WQ 24 (1990)*
30. *Groundwater Investigations in Cass County, Michigan (February 1991)*
31. *U.S. Water Protection and Management: Coordination and Networking Among the Water Resources Research Institutes (July 1991)*
32. *The Saginaw Bay, Michigan Subirrigation Drainage Project 1989-1990 (August 1991)*
33. *Water and Land Use Systems: Research and Educational Programs of the Institute of Water Research and Center for Remote Sensing (August 1991)*
34. *An Introduction to Michigan's Water Resources, Second Edition (December 1991)*
35. *An Assessment of the Resource Base for Agriculture in Michigan in Status and Potential of Michigan Agriculture (December 1992)*
36. *Plugging Abandoned Wells (December 1992)*
37. *ENFORMS (Environmental Information System) (February 1993)*
38. *Saginaw Bay Watershed User Needs Assessment: Accomplishments and Lessons Learned (March 1993)*
39. *Meeting State and National Wetland Goals: A Wetland Conservation Strategy for Michigan (July 1993)*
40. *A Wetlands Information Management System (WIMS) for Facilitating Wetland Decision Making (August 1993)*
41. *Tapping the Source: A Listing of Groundwater Education Materials Available through the GEM Program (November 1993)*
42. *Blue-green Algae: A Problem Species in Inland Lakes (November 1993)*
43. *Family Feud Around Sister Lakes: Too Much of a Good Thing (February 1994)*
44. *Community Planning for Wellhead Protection (April 1994)*
45. *McNabb, C.D., F.M. D'Itri and A. Ushikubo. 1994. Impact of the Zebra Mussel on the Great Lakes Ecosystem. The Michigan Riparian, May, pp. 9-11.*
46. *D'Itri, F.M. (Ed.). 1994. Agricultural Summit I. An Assessment of Future Trends for Pesticide Use in Michigan. Michigan Agricultural Experiment Station and Michigan State University Extension, 145 pp.*
47. *D'Itri, F.M. 1994. Michigan's Water Resources. Special Report 79 on the Status and Potential of Michigan's Natural Resources, Michigan Agricultural Experiment Station, Michigan State University, East Lansing, MI, 35 pp.*
48. *D'Itri, F.M. 1994. Cadmium Poisoning: Toyama, Japan (1912-1955), pp. 345-349; and Methylmercury Seed Poisoning (1971-1972), pp. 383-390. Two chapters in: When Technology Fails, N. Schlager, editor. Gale Research Inc., Detroit, MI.*
49. *D'Itri, F.M. 1994. Ashio, Japan, pp. 55-60; Great Lakes, pp. 381-382; Heavy Metals and Heavy Metal Poisoning, pp. 410-412; Itai-itai Disease3, pp. 454-455; Mercury, pp. 515-516; Methylmercury Seed Dressings, pg. 518; Minamata Disease, pp. 521-522; and Yokkaichi Asthma, pp. 926-927. Entries in: The Environmental Encyclopedia, First Edition, W.P. Cunningham, T. Ball, T.H. Cooper, E. Gorham, M.T. Hepworth, A.A. Marcus, editors. Gale*

Research Inc., Detroit, MI.

50. *Suzuki, N., S. Endoh, M. Kawashima, Y. Itakura, C.D. McNabb, F.M. D'Itri and T.R. Batterson. 1995. Discontinuity Bar in a Coastal Wetland on Lake Huron's Saginaw Bay. J. Freshwat Ecol. 10 (2): 111-123.*
51. *Kang, Y.T., and J. Bartholic. 1994. A GIS-Based Agricultural Nonpoint Source Pollution Management System at the Watershed Level. Center for Remote Sensing, Michigan State University, East Lansing, Michigan.*
52. *Kang, Y.T., L.G. Wolfson, T. Zahniser, and J.F. Bartholic. WIMS: A Prototype Wetlands Information Management System for Facilitating Wetland Decision Making. Proceedings from the April 25-28, 1994, Annual ASPRS/ACSM Convention and Exposition, Reno, Nevada. Volume 1, pp. 290-300.*
53. *Nevala, A., D. Wilson, J. Chamberlain, K. Kirk, R. Kline-Robach and L.G. Wolfson. 1995. Groundwater Stewardship in Michigan: A Manual for Community Action. Institute of Water Research, Michigan State University, East Lansing, Michigan 48823.*
54. *Wolfson, L.G., Y.T. Kang, T.E. Zahniser, and J.F. Bartholic. 1995. A Wetlands Information Management System (WIMS) for Facilitating Wetland Evaluations Completion Report, USEPA Grant No. X995791-02-0, Region V, Chicago, IL*
55. *Belcher, H.W. and F.M. D'Itri, Editors. 1995. Subirrigation and Controlled Drainage. Lewis Publishers, Inc., Chelsea, MI, 503 pp.*
56. *Wolfson, L.G. 1995. Groundwater Quality Testing Program for Agricultural Communities, Michigan Department of Agriculture, Lansing, MI 48909*
57. *Kline-Robach, R. 1995. Raising Awareness and Stimulating Local-Level Groundwater Protection: The Groundwater Education in Michigan (GEM) Program. Conference Proceedings from Conference on Communication and Our Environment, Chattanooga, TN.*
58. *D'Itri, Frank (ed), 1996. Zebra Mussels and Other Aquatic Nuisance Species, Ann Arbor Press, Chelsea, MI, in press.*
59. *Wolfson, Lois, 1996. Water (Chapter 3) in A Framework for Assessing Environmental Health in Michigan, Michigan Public Health Institute, Lansing, MI, in preparation.*
60. *Brown, Elaine, 1996. Land (Chapter 4) in A Framework for Assessing Environmental Health in Michigan, Michigan Public Health Institute, Lansing, MI, in preparation.*
61. *Kline-Robach, Ruth and Lois G. Wolfson, (mng. ed), 1996. Groundwater Stewardship in Michigan: A Community Action Guide, Michigan Farm Bureau.*
62. *Kline-Robach, Ruth (ed), 1996. Understanding Groundwater: A Training Tool for Groundwater Technicians, Institute of Water Research, Michigan State University, East Lansing, MI.*
63. *Bartholic, J.F. 1996. Invited paper at the World Resources Institute Non-Point Source Pollution in the Great Lakes Basin: Challenges and Regional Opportunities Conference, presented Sept 12-13, Chicago, IL "How BIG is the Problem? Issues and Trends for the Great Lakes," in press.*
64. *Bartholic, J.F. 1997. The State of The Great Lakes Annual Report, "Profiling Agriculture in the Great Lakes Basin." Michigan Department of Environmental Quality, Office of the Great Lakes, pp. 24-25.*
65. *Ouyang, D., and J. Bartholic. 1997. Predicting sediment delivery ratio in Saginaw Bay Watershed. In: The 22nd National Association of Environmental Professionals Conference Proceedings, pp. 659-671. May.*
66. *Ouyang, D., and J. Bartholic. 1997. Assessment of non-point source pollution potential from agricultural phosphorus in the United States. ASAE paper 97-2003. In: Applications of Emerging Technologies in Hydrology, pp. 9-12.*
67. *Ouyang, D., and J. Bartholic, 1997. The National Agricultural Pesticide Risk Analysis (NAPRA) process and its implementation trials. Agronomy Abstracts (1997), p. 263.*
68. *Wolfson, Lois, 1997. Draft chapter for Citizen's Guidebook for Wetlands Assessment of*

Functions and Values, co-sponsored with Department's of Crop and Soil Science and Resource Development.

69. *Kline-Robach, Ruth, 1997. "Michigan's Drinking Water" (GEM) Home Page development (http://www.gem.msu.edu).*
70. *Kline-Robach, Ruth, 1997. A three-part article on drinking water protection in Michigan Counties.*
71. *Kline-Robach, Ruth, 1997. A two-part article series on drinking water protection from a township perspective in Michigan Township News.*
72. *Kline-Robach, Ruth, 1997. A series of 10 fact sheets for local officials: Small-Scale Septic Systems: Their Threat to Drinking Water Supplies and Options for Local Government; Alternative On-Site and Community Collection and Treatment Technologies; Management Programs for On-Site and Community Wastewater Treatment Systems; The Role of Local Government in the Proper Closure of Abandoned Wells; Using Site Plan Review to Protect Drinking Water Sources; Recommended Site Plan Review Standards for Protecting Drinking Water Quality; Model of a Hazardous Substances Reporting Form Used During Site Plan Review; Model of an Environmental Permits Checklist; The Potential Contributions of Local Fire Departments to Protecting Drinking Water; The Regulatory Framework for Michigan Agriculture.*
73. *D'Itri, Frank (ed), 1997. Zebra Mussels and Other Aquatic Nuisance Species, Ann Arbor Press, Chelsea, MI, 638 pp*
74. *D'Itri, F.M. 1998. Environmental Contamination: An Anthology. International Training Workshop on Environmental and Occupational Health, U.S. National Institutes of Health and Bulgarian Ministry of Health, Velingrad, Bulgaria, 56 pp.*
75. *Itakura, Y., J.S. Eades, F.M. D'Itri, M. Kawashima, S. Endoh, and H. Kitamura. 1999. Integrated Environmental Management: Development Information and Education in the Asian Pacific Region, Ann Arbor Press, Chelsea, MI 488 pp.*
76. *D'Itri, F.M. 1999. Environmental Contamination and the Information Highway. In: Integrated Environmental Management: Development Information and Education in the Asian Pacific Region, Ann Arbor Press, Chelsea, MI, pp. 211-222.*
77. *D'Itri, F.M. 1999. What Education and Information Systems Can Do To Help Solve Environmental Problems: A Summary. In: Integrated Environmental Management: Development Information and Education in the Asian Pacific Region, Ann Arbor Press, Chelsea, MI, pp. 271-277.*
78. *Ouyang, D., J. Bartholic. 1998. Water quality assessment in agricultural watersheds. Agronomy Abstracts (1998). Baltimore, ML.*
79. *Ouyang, D., J. Bartholic, and E. Hesketh. 1998. Risk-based analysis of pesticide applications in agricultural croplands. In: The Proceedings of the Watershed Specialty Conference - Watershed Management: Moving from Theory to Implementation. May 3-6, 1998, Denver, CO. pp 1089-1096.*

Slide-Tape Programs

1. *Lakes and Water Quality*
2. *An Introduction to Michigan's Water Resources*

Video-Tape Programs

1. *The Michigan State University Lake Management Self-Help Program*
2. *Lake Harvesting*

3. *The Trouble with Toxics (support given to Michigan Sea Grant)*
4. *Groundwater: The Unseen Resource (support given to Cooperative Extension)*
5. *Groundwater and Your Family's Health (support given to Cooperative Extension)*
6. *Agriculture and Groundwater Contamination: Exploring the Issues (support given to Cooperative Extension)*
7. *Agriculture and Groundwater Contamination: Problems and Prevention*
8. *Where the River Flows Clean*
9. *Communities in Action: The Wellhead Protection Program*

Computer Programs

1. *Simulation Model: Farm Pond Construction and Fish Stocking Computer Game*
2. *The Watershed and Your Lake*
3. *Computer Assisted Recreational Planning Model*
4. *Computer Assisted Aquatic Plant Identification*
5. *Water Trivia Challenge*
6. *Where to go for Assistance: The Drinking Water Testing Program*
7. *Groundwater Simulation Scenarios*
8. *ENFORMS: Environmental Information System, 1994*
9. *WIMS: The Wetlands Information Management System*
10. *The Cass County Experience (Computer Animation)*
11. *MFINS: Michigan Fisheries Information System*
12. *WINFO-X: Watershed Information Exchange*
13. *Introductory Land and Water Learning Module, 1997*
14. *Michigan Ag Profile, 1997*
15. *Wetlands Information Management System II (WIMS) for Local Decision Makers, 1997*
16. *Wetlands Tracking System-in progress, 1997*
17. *Water Quality Data Access System-in progress, 1997*
18. *Wetlands Tracking System (WTS) pilot version complete and in use, 1998*