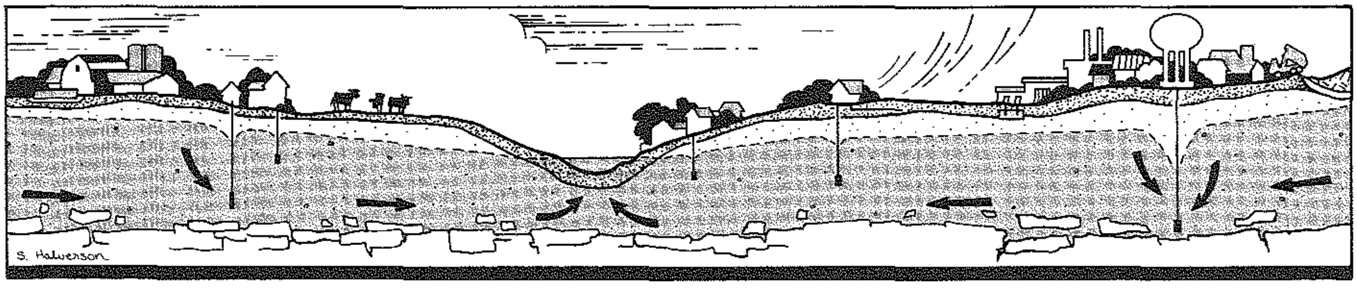
Wisconsin Department of Natural Resources
Wisconsin's Groundwater Management Plan
Report No. 12

Wisconsin Geological and Natural History Survey
Special Report 9

A Guide to Groundwater Quality Planning and Management for Local Governments

Stephen M. Born
Douglas A. Yanggen
Alexander Zaporozec

1987



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PREFACE

The 1983 Wisconsin Act 410 recognizes local units of government have an important role in protecting groundwater quality. This guide is intended to foster cooperation between local government and state agencies by explaining how state agency programs can be coordinated with local planning efforts to improve groundwater quality and prevent groundwater contamination. It is published as part of the continuing joint efforts of the Wisconsin Geological and Natural History Survey and the Wisconsin Department of Natural Resources to provide useful information to local governments that can increase both their effectiveness and their efficiency while providing a statewide perspective on groundwater quality concerns.

The Wisconsin Geological and Natural History Survey and Wisconsin Department of Natural Resources have a long history of concern for sound management of the state's natural resource heritage. This publication is one in a series of Survey reports dealing with the characterization, assessment, and use of Wisconsin's groundwater resource. The authors have many years of combined experience in groundwater planning and management. Their expertise has allowed them to pull many dimensions of resource management together, providing an overview and synthesis of groundwater quality planning that focuses on a local governmental perspective. The table of contents can serve as a sourcebook for particular groundwater problems addressed by the report. Although the report is specific to Wisconsin, the overall approach can be readily adopted elsewhere by governments seeking to protect and manage their groundwater resource. The rapidly changing institutional environment affecting groundwater makes it imperative for the reader to stay current with state and federal laws affecting groundwater management. It is within this context that the Survey, along with the Wisconsin Department of Natural Resources, is publishing this report with the hope and expectation that it will contribute to better management of this vital natural resource.

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Because of the harmful effects of polluted groundwater on human health and economic activities, local governments are becoming more and more concerned about protecting the quality of their groundwater. Local officials who recognize the need for a systematic program of groundwater quality management often need help in finding and using information to manage their groundwater resources. This publication provides information about specific strategies and actions to develop a program for maintaining and improving the quality of groundwater.

One basic element of a systematic program is identifying goals and objectives, the people who will participate, and the scope of effort. Next, it is important to identify what land-use activities have the potential to cause pollution and to determine whether these practices are being carried out in pollution-sensitive areas. This requires an evaluation of how the environment can affect or be affected by pollution. Soils and geologic materials in some areas can attenuate certain pollutants before they reach the groundwater; in other areas, pollutants can readily enter groundwater.

The next step involves an inventory and analysis of the existing condition of the groundwater. Documenting current quality conditions is important for determining any future quality changes, for identifying areas where groundwater quality is impaired, and for relating the extent of impairment to different land uses or sources of pollution.

Once they have collected background information, local governments are in a position to determine the type of management techniques needed for the area's problems. Local officials may decide to undertake a comprehensive program or instead focus on either a particular source of pollution or specific areas where several potential sources of pollution are a problem. To determine what sources of groundwater pollution should be controlled, each local government needs to consider the size of the population potentially at risk, the toxicity of particular pollutants and their probable health effects, and the geographic extent of the area or aquifer affected by pollution. Local officials may decide to designate special management areas for protection: naturally vulnerable areas, potential problem areas, or well-protection areas.

The approach can be regulatory (such as placing a system of legal constraints on certain land-use activities), nonregulatory (such as recommending best management practices or developing educational programs), or a combination. Local governments should take state regulations into consideration so that local and state programs complement each other. On the basis of discussion with technical advisors at the state and local level and the information presented in this publication, local decision makers can shape strategies and actions best-suited to protect groundwater resources.

Chapter I.

INTRODUCTION

Importance of Local Groundwater Protection

Groundwater is a valuable resource in Wisconsin--it supplies approximately 94 percent of Wisconsin cities and villages and almost all the rural population with drinking water, and is vital to the state's agricultural, industrial, and business enterprises. Unfortunately, certain land uses can result in pollution of groundwater; this has already occurred in some areas of the state. Cleaning polluted groundwater can be costly and, in some cases, almost impossible.

However, cities, villages, towns, and counties can use their zoning authority to regulate proposed land uses that have the potential to pollute groundwater. Zoning and other local powers--regulatory and nonregulatory--can supplement state programs designed to control major pollution sources. By working together, local and state governments can implement the programs needed to protect groundwater.

Overview of the Report

This publication is designed to help those in local governments develop the groundwater protection programs that are best suited to the needs of their communities. Local elected officials, their technical advisors, and interested citizens who are concerned about groundwater and making recommendations for its protection need to answer certain basic questions, including 1) What kind of information do we need; 2) Why do we need it; 3) Where can we find it; and 4) How can we use it to protect our groundwater? This publication provides the answers to these questions.

We describe how key information about local conditions can be gathered and then used to develop an acceptable plan to protect groundwater quality. The plan can be comprehensive or more limited in scope. We discuss how to identify and work with key participants; to inventory and assess environmental characteristics; to delineate areas vulnerable to pollution; to identify and select management strategies; and to implement the plan's recommendations through a series of interrelated steps (fig. 1).

We have also included a description of the availability of information and technical assistance and a summary of the responsibilities of various state agencies with respect to groundwater management activities that relate to local protection efforts. We present a variety of regulatory and nonregulatory local management options, and provide an overview of the legal authority of cities, villages, towns, and counties that defines the appropriate role of the various local governmental units. Finally, we discuss assessing risks and the factors to be considered in selecting a groundwater protection strategy.

Addressing Specific Local Conditions

There are several general management approaches that local governments can follow to protect groundwater quality. The actual management plan, however, should be tailored to reflect the conditions and needs of that locality. Situations vary from locality to locality; soils and hydrogeologic conditions differ throughout the state; more information is available in some areas than in others; some local governments have more staff and greater technical and financial resources. Groundwater problems and local residents' perceptions of the problems also vary from community to community. The existing problems and the resources available to deal with them will affect the scope of the local effort; because no two communities are exactly alike, management programs will not be identical. To choose the measures best suited to meet a community's particular needs, the following questions should be addressed:

1) Where do we get our groundwater from?
    a) What type(s) of aquifers do we have?
    b) Where are they located and what is their relative depth?
    c) How much water can we get from them?
    d) What is the relationship of our groundwater and surface water resources?

2) What do we know about our wells?
    a) What types of wells do we have - public or private, deep or shallow?
    b) Where are they located and how are they constructed?
    c) Are sites for future wells identified?

3) What is our water being used for?
    a) What is the amount and percentage of water consumed for residential, industrial, commercial, and agricultural uses?
    b) What will future demands be for each use?
    c) Do we have adequate supplies for current and future uses?

4) Does our community have an adequate supply of good quality water?
    a) What are the existing water characteristics?
    b) Is it free of bacterial and chemical pollutants?
    c) Do we have systematic testing/monitoring?

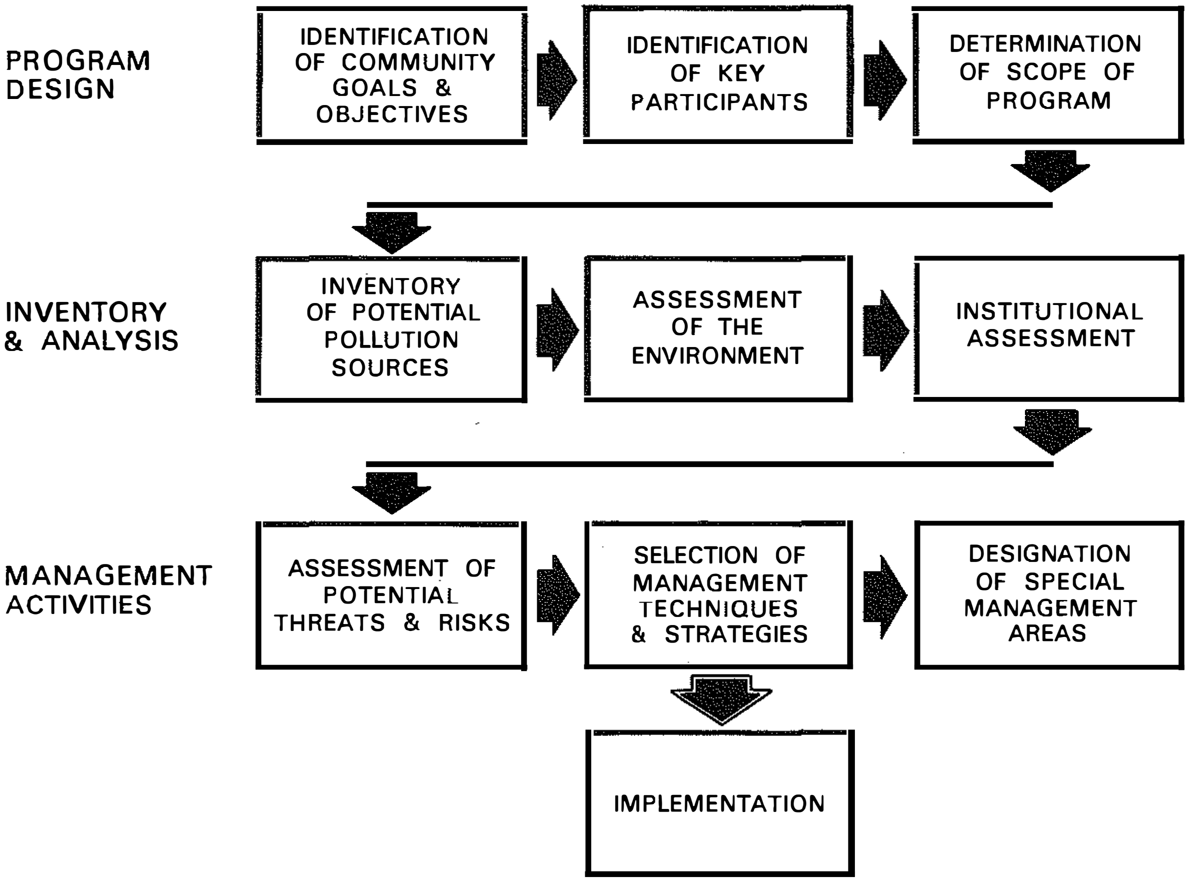


Figure 1. Major stages in developing and implementing a groundwater quality management program.

5) Are there some areas that are more susceptible to pollution than others?
   a) Which areas are particularly susceptible to groundwater pollution?
   b) Are we located in an area where most of the soils and geologic formations make the groundwater particularly susceptible to pollution, such as the Central Sands or "karst" areas?

6) What are the sources of potential pollution problems?
   a) Which particular activities or land uses are potential sources of pollution?
   b) What general categories of land use are associated with these activities and what are future trends?
   c) Which activities produce or use substances deemed hazardous to health by federal or state agencies?

7) Are there areas where pollution already exists or is likely to exist?
   a) Where are spills of hazardous materials located?
   b) Where are abandoned and operating waste disposal sites located?
   c) Where are underground storage tanks located?
   d) What other sources may have caused pollution?

8) What groundwater management responsibilities does each governmental unit have?
   a) What is the role and authority of cities, villages, towns, and counties and which local agencies are responsible?
   b) What is the responsibility of state government and which state agencies are in charge?

9) How can we protect and manage our groundwater supply?
   a) Through local governmental regulations?
   b) Through nonregulatory governmental action?
   c) In cooperation with other local units?
   d) In cooperation with the state?
   e) Through voluntary private action?

10) Who will be affected by the management decisions and who will pay?
   a) Users of groundwater?
   b) Producers or users of potential pollutants?
   c) Governmental agencies?
   d) Tax-paying public?

11) How do we get started?
   a) Who do we call for help?
   b) How do we organize locally?

Information Needs for Groundwater Quality Management Decisions

Protection of groundwater requires a good information base that answers the preceding questions. A protection program should be based on a knowledge of groundwater resources, their location and quality, the hydrogeologic setting with respect to the potential for pollution, and existing and anticipated pollution sources and land uses likely to affect groundwater. Table 1 summarizes key components of an information base. Some of the needed data are available from state and federal agencies, but other data must be gathered or compiled. The degree to which a sound protection program can be structured depends on the scope and quality of the information base.

Table 1. Information base components of a groundwater quality management program

Information component	Related chapter of this report
Hydrogeology	V
• soil and unsaturated zone characteristics	V
• aquifer characteristics	Appendix A
Water use	III
• locations and purpose	
• amounts and trends	
Water quality	III
Potential pollution sources and characteristics	IV
• waste disposal	
• agricultural activities	
• chemical storage and handling	
• other	
Properties of chemicals	I
Population and land-use patterns	I

Hydrogeologic Setting

A basic need of a groundwater quality management program is understanding the system's hydrogeology. This helps determine the water-yield characteristics of an aquifer, the suitability of water quality for various beneficial uses, the degree of vulnerability of the aquifer to pollution, and the type of pollution control program needed. Appendix A contains information on Wisconsin's aquifers.

The hydrogeologic setting includes soils, surficial geology, bedrock geology, and groundwater and its relation to surface water. These elements are important because they can affect the extent to which pollutants enter groundwater and the way they move in the aquifer. Some combinations of hydrogeologic factors have a greater potential for restricting the introduction of pollutants or for attenuating them. For example, an area with a deep water table, fine, slowly permeable soils, clay subsoil, and relatively impermeable bedrock would generally be less susceptible to pollution than one with a shallow water table, coarse and rapidly permeable soils, a sand-and-gravel subsoil, and fractured dolomite. These geologic characteristics occur in differing combinations in different parts of the state; thus, it is important to know local conditions. Methods to evaluate these factors are discussed in chapter V. These methods assess the ability of a particular physical setting to attenuate pollution and assist in delineating "vulnerable areas" where pollutants have the greatest potential for reaching groundwater.

Water Use

Knowledge of groundwater withdrawals and their use is another key component of a groundwater quality management plan. Water quality can be altered by pumping and lowering the water table. If the cone of depression created by pumping a well near a stream extends and reaches the stream, it will induce flow of surface water (which may be polluted) toward the well. To get a comprehensive picture for management of groundwater quality, information is needed on the location of water wells, the amount of water being extracted, purpose for which the water is to be used (domestic, industrial, agricultural, etc.) (see chapter III), and related surface water uses. Historical trends and distribution of groundwater uses in Wisconsin are presented in Appendix A.

Water Quality

Water quality is of special significance in formulating a groundwater quality management program. First, information on groundwater quality provides a base for determining any future changes in groundwater quality. (The steps involved in gathering data on existing groundwater quality are discussed in chapter III.) In addition, knowledge about the degree of chemical pollution in aquifers can help identify potential problem areas and indicate the measures needed for pollution control as well as cleanup. Existing water quality information is often inadequate to make decisions about groundwater pollution control. Because pollution is frequently local and may move quite slowly in an aquifer, sampling for chemical pollution must be extensive and precise. The results of this sampling should then be checked for compliance with Wisconsin groundwater and drinking-water standards.

Potential Pollution Sources

To protect groundwater quality, it is necessary to know the type, amount, and location of potential pollution sources and the pattern of production or use of potential polluting substances. An inventory and assessment of potential pollution sources can provide this information (see chapter IV of this report). Individual potential pollution sources can then be mapped and this information compared with data on water-supply systems and on spatial distribution of pollution-sensitive areas. The information can then be used to target efforts on pollution prevention, source reduction, aquifer and water-supply protection, water-quality monitoring, and detection of improper waste disposal and other practices.

Properties of Pollutants

Substances vary widely in their potential to pollute groundwater. They range from relatively innocuous to those listed by the state and federal government as hazardous materials (Wis. Administrative Code, chap. NR 101 and chap. NR 158). The risk associated with a particular pollutant varies with the nature of the pollutant. The rate of movement and fate of chemicals in the subsurface are affected by their physical, chemical, and biological characteristics. Knowing the properties of these chemicals is useful in determining the extent of groundwater pollution and methods for aquifer restoration, and in implementing regulations concerning chemical usage and control.

Population and Land-Use Patterns

The impacts of projected population increases or decreases and industrial and land-use changes are important elements in the management of water quality. This information can be used to determine potential impact on the aquifers. Specific uses can be related to water quality. For example, irrigated farmland can contribute a variety of chemicals to the unsaturated zone or to the groundwater. If this land was converted to urban use, problems with drinking-water quality could ensue. Increased pumpage, resulting from population growth, may increase the likelihood of pollutants reaching a well. Septic tank effluent from large, new unsewered subdivision developments on unsuitable soils can cause considerable water pollution problems. Newly developed industries can pollute groundwater through spills and leakage of storage tanks. A decrease in population growth or shifts in industrial location and agricultural operations may reduce the amount of pollutants generated, although residual pollution may remain for a long time.

Data Collection and Management

Physical resource information, pollution source inventory data, and land uses can be more easily analyzed when displayed on maps where spatial relationships can be seen. The information may be collected using larger scale maps (for example, 1:24,000 for county studies or 1:2,400 for municipal planning purposes) or aerial photographs. However, there should be a standardized scale for all maps used for overlaying, compositing, and analysis. A recommended scale is 1:100,000, because it is compatible with other resource information published by state agencies. This scale will allow information generated during the planning process to be readily combined with maps made by other agencies. Using information at a scale of 1:100,000 must be done carefully, however, because the scale lends itself to general planning purposes rather than detailed investigations.

When all maps are prepared at the same scale, they can be overlaid in various combinations. These overlays allow for some analysis and estimation of pollution potential and comparison of available information. Such analyses can lead to considerable savings during planning by screening areas before expensive, detailed site investigations are performed.

To successfully cope with the flux of data, an adequate, centralized data management system should be developed. It should be accessible and kept current by maintaining good records of all information collected, such as water-quality information, soil information, and geologic information. Accurate information on the location of wells, septic systems, potentially polluting land uses, and areas of groundwater pollution incidents must also be kept. The information is not useful, however, unless it can be easily retrieved, unless it includes adequate geographic description to find the location of points in the field, and unless it is available to and known by a variety of users. Local units of government considering automation of land-resource information should consider how to incorporate groundwater-related data into their systems. They should also check with other local agencies and state agencies (especially DNR) to insure compatibility with existing data systems. Further information on the application of computerized geographic information systems is available from the UW-Madison Institute for Environmental Studies.

Local data collection and management programs should be developed in a format that will facilitate long-term needs. The data management system should be flexible and easy to access and use. Setting up a local data management system is complicated and expensive, although long-term benefits would outweigh costs. Local governments can presently use existing data bases of other agencies (DNR, USGS, SCS, etc.) and can make cooperative agreements with state agencies about data sharing.

Chapter II.

SCOPE OF THE LOCAL EFFORT AND ORGANIZING FOR ACTION

Emergence of Local Groundwater Concerns

How groundwater quality protection emerges as a local concern influences how the issue is perceived, the importance attached to it, the nature of the response by local government, and the prospects for implementing a planned program of action. A general groundswell of public opinion for developing a comprehensive groundwater management plan and action program in the absence of a problem is rare. Far more often, action is called for in response to a real or perceived threat to human health. For example, a local government may find itself "suddenly" addressing groundwater management following media coverage of a local pollution incident. The perception of the problem will vary depending on the severity of contamination and the size of the population at risk. Widespread pollution of groundwater by pesticides will trigger far greater attention than infrequent localized complaints about taste and odor problems from private well owners. Pollution of several municipal wells by volatile organic chemicals from a landfill will provoke a far different governmental reaction than pollution from a leaky underground gasoline storage tank that affects only a few citizens. If residents perceive that their groundwater resources are at risk and that there may be serious health and fiscal consequences, a local government will react with a different level of interest and commitment to groundwater planning than it will to a state administrative requirement for a groundwater management plan.

In brief, how the groundwater issue is addressed at the local level depends to a substantial degree on how and what problems have arisen, or are perceived to have arisen. The extent of local commitment to deal with groundwater quality issues will be influenced by the nature and number of the affected interest groups calling for action. Accordingly, the origins of the issue should be a serious consideration when devising a groundwater management strategy--influencing the scope of the planning effort, the focus of inventory and analysis activities, and the character of measures addressing identified problems.

Scope of the Planning Effort

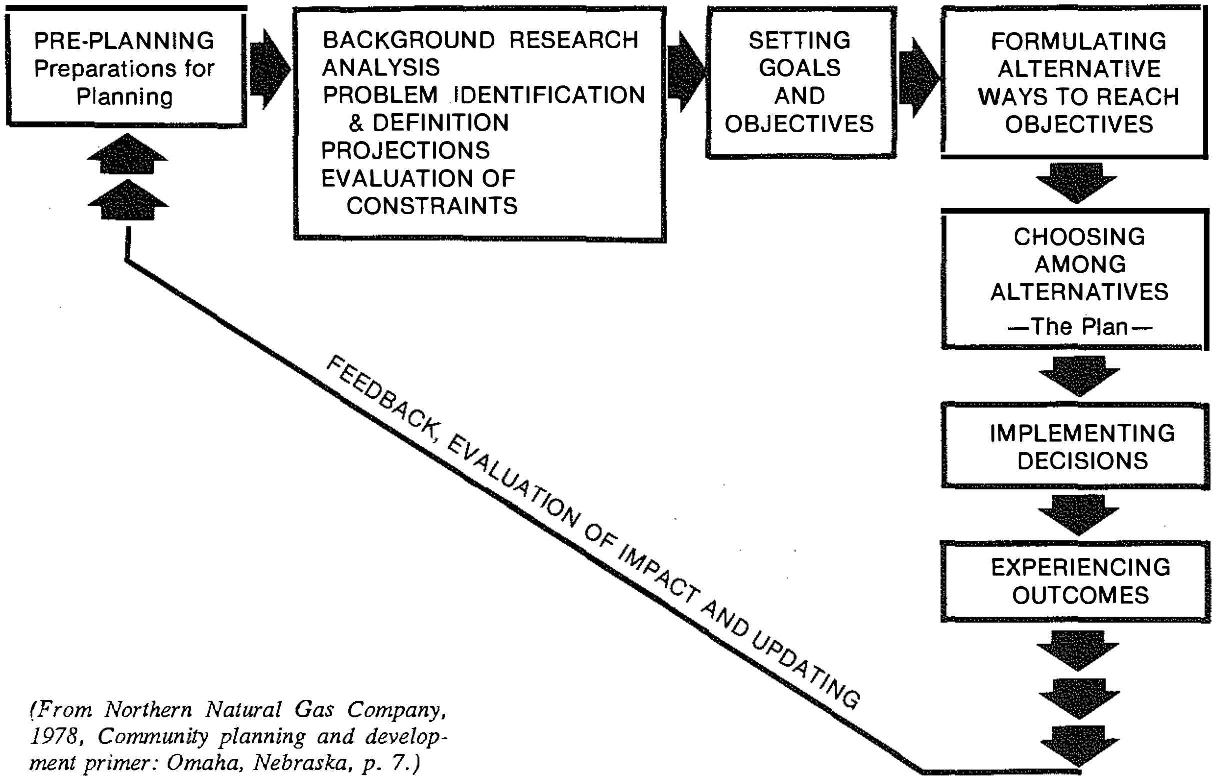
There are various approaches to groundwater planning. Most resource managers would like to have a well-documented, systematically prepared comprehensive plan to guide decision-making about groundwater protection. This comprehensive plan would include a thorough and detailed analysis of the hydrogeologic setting and the groundwater resource and an assessment of the natural and human factors influencing the resource. A complete inventory and assessment of all existing and potential sources of pollution would be undertaken, and scientific and technical analyses would be based on a thorough, technically sound data base.

The components of a comprehensive groundwater protection program would result from a rational comprehensive planning process (fig. 2). A comprehensive statement of goals and objectives would guide subsequent steps. The inventory, forecasts, and problem analyses would serve as the basis for designing and evaluating a full range of alternatives. The "best" alternative would be adopted by decision-makers with provisions for systematic monitoring, evaluation, and "feedback" to allow for essential revisions.

This approach is desirable because it avoids piecemeal solutions. A comprehensive approach encourages sound management by requiring a sound data base and technical analysis. It also recognizes interrelationships between the many resource variables, e.g., water quality/quantity and land use/surface water/groundwater interactions. By identifying all alternatives, an optimal course of action can be found and innovative solutions will not be overlooked. A comprehensive approach maximizes the chances that a particular management action will accomplish its goals and objectives. It can reduce long-term costs and delays, capitalize on mutually reinforcing programs or opportunities, and build public confidence. Furthermore, it is easier to relate a comprehensive groundwater planning approach to broader water quality, natural resources and general comprehensive planning efforts of areawide water quality and regional planning agencies. In short, comprehensive planning and management approaches are perceived, especially by the professional and scientific community, as more effective and efficient than dealing with needs and problems on a source-by-source or pollutant-by-pollutant basis.

This ideal approach is rarely realized. Efforts to pursue the comprehensive planning approach suffer from a number of difficulties. The data needs for comprehensive analysis are not only costly, but rarely can be met. All possible alternatives can never be identified and evaluated. The final product of such efforts--the traditional comprehensive plan--tends to be a static product, fixed in time. Preparation of such a plan can require an unacceptably long period of time and intervening events may render the plan and its recommendations irrelevant. Comprehensive planning rarely achieves the level of specificity necessary for resolving conflicts. It is difficult to frame the issues and solutions in sufficient detail to capture the attention of those constituencies and individuals ultimately affected by the plan. Furthermore, governing bodies of elected officials are not disposed to adopting and supporting comprehensive plans, especially given the incremental nature of most governmental decision-making and the political desire to keep one's options open as long as possible.

Accepting the technical desirability of a comprehensive plan to guide groundwater-management actions and the difficulty of preparing a usable action-oriented product, what can local governments do? An alternative to comprehensive planning is to



(From Northern Natural Gas Company, 1978, Community planning and development primer: Omaha, Nebraska, p. 7.)

Figure 2. The planning process.

reduce the scope of planning. Although the term "Strategic Planning" has recently become popular to describe this approach, this kind of reduced planning has been with us for many years.

Reduced versions of comprehensive plans should consider all key factors and issues, acknowledge interrelationships, recognize limitations stemming from inadequate data, and acknowledge the uncertainty that is inherent in analysis and forecasting. At the same time, the planning process must be cognizant of financial constraints, time limits, and the decision-making processes. A reduced plan might: 1) focus on a limited set of problems/issues; 2) vary the level of detail of recommended actions based on the likelihood of implementation; 3) proceed in stages over a period of time rather than simultaneously identifying best solutions to all problems; and 4) identify unresolved issues and contingencies. Over a long time, such a selective approach may result in a more or less comprehensive plan. However, reduced planning allows pressing problems to be addressed and solved, while providing "real-life" feedback to ongoing planning studies. It allows political support to develop as successes are achieved and acknowledges that programming, action, and implementation are what make planning relevant.

There are many ways that traditional comprehensive planning efforts can be scaled down and modified so that some needed groundwater protection planning activity can be started. Instead of dealing with the full array of perceived problems and threats to groundwater, attention might initially be limited to dealing with the problems deemed most serious. For example, the planning effort could focus on protecting existing and future community drinking water supplies. Sources of potential and existing groundwater pollution not affecting these supplies would not receive the same level of planning and analytical effort. Thus, focusing on an areal approach (e.g., high priority special management areas) is one way to limit the scope of planning, and implement an important partial groundwater protection effort. Another approach would be to focus on a specific pollution source of local concern, i.e., underground storage tanks or a particular agricultural chemical. A reduced effort could also involve focusing on a single phase of the planning process, e.g., inventorying all pollution sources within a local jurisdiction or initially emphasizing a public educational effort. Some further general guidelines for limiting the scope of planning are presented in Chapter VIII.

It is important that the reduced approach be selected carefully with an eye toward what will be ultimately needed for an effective planning effort. Planning should be designed so that individual activities build on each other and move toward a more comprehensive view of the resource and its problems. The public may be more receptive to a reduced rather than a traditional comprehensive planning approach, because it tackles perceived pressing problems more responsively. However, any limited planning also entails certain risks and pitfalls. These include potential conflicts with other programs, unidentified side effects, duplication of effort, and a tendency to be reactive vs. anticipatory. Thus, reduced planning for groundwater protection should be placed in the broadest possible context of planning activities to maximize its effectiveness.

Establishing Goals and Objectives

Whatever the scope of the planning effort, it is critical to develop a coherent statement of goals and objectives. Goals and objectives define what you want to accomplish and provide the basis for measuring your progress. Assessing progress is a major part of evaluating your plan and its implementation. It provides important information for mid-course corrections, either in the goals and objectives, or in the means to achieve them.

While goals state what end results are desired, objectives are specific and should elaborate on, and preferably quantify, a goal. Goals and objectives should not simply be a product of agency staff. It is important for policymakers and the affected public to enter the planning effort at this point if they are expected to endorse the resulting action plan. At the heart of developing goals and objectives is the question, "Whose goals and values will direct the planning process and define the product?" Rather than have the entire planning effort be undermined by disagreements over a comprehensive set of goals, it may be more effective to agree on a limited number of high priority goals and objectives that can be modified at a later time.

Goals and objectives will vary from place to place based on needs, types of existing and potential problems, local constituencies and leadership, hydrogeologic and related natural resource considerations, and other factors. There is some disagreement among professional planners as to whether goals should be readily attainable--i.e., realistic--or whether they should aim toward more difficult targets. Each local unit of government will have to decide what course to pursue. It's also important to cross-check goals for groundwater protection and management with other local and regional governmental programs and goals to insure consistency in program direction.

The following list of goals is indicative of the wide range of choices available to local governments. The listing is not complete, but hopefully can serve as a starting point for local governments. The goals may include:

- Protect, maintain, and improve the quality of groundwater;
- Protect municipal water supplies from pollution;
- Encourage wise land-use decisions that will prevent groundwater pollution;
- Increase public awareness of the local groundwater resource, its use, value, problems, and possible solutions;
- Establish a data collection and analysis program;
- Maximize interagency coordination in groundwater management.

To illustrate how objectives differ from goals, the following list of hypothetical objectives are presented as they relate to the goal, "Protect municipal water supplies from pollution":

Recognize well-protection districts as a tool for protecting groundwater;
Establish land-use controls to protect water quality from developmental impacts in all well-protection districts by 1990;
Review sewer service areas, including those in developing areas, to determine any adverse impact on municipal water supply wells;
Have a water quality monitoring program, in collaboration with the state, operative for all municipal well fields by 1992.

Those issues of greatest concern to a local unit of government are best identified when initially developing a statement of goals and objectives. The level of elaboration is a matter of community choice. Like every phase of a realistic planning process, the goals and objectives can be reviewed as added concerns become high priority agenda items for local citizens and policymakers.

Identifying Key Participants

The first step in organizing the planning process is to identify the entity responsible for the technical staff work of preparing the plan. Although this responsibility could be assigned to a single local agency, the complexity of groundwater planning suggests the need for an interagency, intergovernmental effort. Even if a lead agency, a single staff person, or hired consultant is charged with primary responsibility for assembling the plan, cooperation with numerous other organizations and departments will be necessary. In reality, a working group will generally need to be assembled as contributors to the planning process. In Wisconsin, a typical "team" for preparing a county groundwater plan might include: the local Soil Conservation Service and/or county land conservation department conservationist; the University Extension county agricultural and resource agents; planning, zoning, and health department staff; and representatives from the municipal health department and municipal water utilities. This team can be supplemented by other parties, such as DNR district specialists, as available and needed. As the work effort evolves, all team members must understand what is expected of them and their agencies. Responsibilities for providing information, analysis, and writing specific parts of the plan must be clear. The overall responsibility for assembling the pieces, writing and editing, and overseeing completion of the final work product must be assigned without ambiguity.

Many local governments will consider forming one or two other committees to assist the groundwater planning work--a Technical Advisory Committee (TAC) and a Citizen Advisory Committee (CAC). A TAC could be drawn from state agency staff, federal agency personnel, and selected experts from educational institutions or industry. A TAC could assist with particularly complex or highly scientific analytical work when the requisite expertise is not available in local departments. For example, the TAC may be able to draw on experience with similar problems in other localities and/or may also be able to identify information needed for the planning effort. The TAC could further be used to critically review data, analyses, and recommendations. This outside technical review could strengthen and validate the plan and proposed action program.

Planning efforts are usually accompanied by the formation of a Citizen Advisory Committee, which represents a variety of concerns and interests during the plan development process. The expectations associated with forming a CAC must be carefully considered during the planning process. Is the CAC to take the lead in developing and conducting general information and education efforts for the local public? Is it expected to design and/or conduct a public participation program about the plan and its recommendations? Or is the CAC to be a surrogate for the public at large by providing inputs and reactions to the plan from the perspectives of the numerous citizen interests? Whatever their purpose, CACs offer the opportunity to involve community groups, business and industry, environmental organizations, and others directly in the plan development process. If supportive of the final plan, they and the constituencies they represent can provide critical support for subsequent adoption and implementation of the plan. Further information is available in an excellent guide to the establishment and functioning of CACs (Lageroos, 1982).

Chapter III.

INVENTORY AND ASSESSMENT OF LOCAL WATER USE AND WATER QUALITY

As a part of initiating a groundwater protection plan, local government must inventory and assess the existing conditions of its groundwater resource. Appendix A provides a general description of groundwater resources and their use and quality and major groundwater problems in Wisconsin. Information about groundwater use and quality gathered at the state level needs to be segregated and made useful for local purposes. Supplemental information regarding the specifics of local water conditions should be compiled. In general, this local overview will rely on existing primary and secondary data; however, it may indicate aspects of water use and quality that warrant further investigation.

Assessing Local Groundwater Use

A local government and its citizens must have an appreciation and understanding of the significance of their groundwater resource before they can commit resources to tackle groundwater protection. Information providing an overview of how much groundwater is presently used and for what purposes must be assembled. Future demands on the groundwater resource and its ability to meet increasing demands should be estimated. The importance of the groundwater resource in meeting present and future needs must be clearly perceived before there will be the base of local support needed to successfully implement a groundwater protection program.

General information on water use in Wisconsin is presented in Appendix A. As noted in Appendix A, there is limited statistical information on water use on a county-by-county basis. The summary in table A1 provides a good starting point for examining water use at the county level. Historical information (to establish trends in water use) and estimates of future demands must be derived indirectly from a variety of data sources. Figure A3, which show groundwater use as a percentage of total use, provides a good indication of the present and potential importance of groundwater to a particular county. As noted in Appendix A, public supplies are the most important use of groundwater in Wisconsin, followed by agricultural uses. Groundwater also plays an important role in sustaining the baseflow of surface waters, thus protecting groundwater contributes to the overall protection and management of all our water resources.

Getting a handle on water use in a county or community means gathering information on historic, present, and projected use for each of the major water user groups--public and private water supplies, agricultural, and industrial. Records of public withdrawals (for community and noncommunity systems) are readily obtainable. They are kept on an annual basis by municipal utilities, the Department of Natural Resources (DNR) Bureau of Water Supply, and the Public Service Commission. The U.S. Geological Survey (USGS) maintains a state water-use data system (SWUDS) established in 1979. Annual water-use data can be retrieved by county or basin in tabulated or map form. These records can be used to compile historic and present use rate and volume information. Estimating future municipal water demands may require the services of a consultant. However, for rough planning purposes, future needs could be based on population projections--available from the Department of Administration (DOA) or the Applied Population Laboratory, UW-Madison--and per capita water consumption based on past usage. Of course, if major new users are anticipated or consumption patterns are changing, estimating future needs will require more rigorous analysis. This is especially true when planning for the water supplies of larger municipalities.

Water use and future needs in rural and suburbanizing areas served by private water supplies must be estimated indirectly; good data are not generally available. Private water-supply usage over time can be derived by subtracting the number of persons in cities and villages served by municipal wells from the total county population. The resulting number of people using private wells can then be multiplied by average water consumption per capita (which can be estimated as 60 gallons per day in Wisconsin) to estimate private water use. Future demands could be estimated by subtracting the portion of future population growth predicted to occur within existing local sewer service areas. County and regional planning agencies and the DNR can provide assistance in obtaining and utilizing this data. Population and land and water use projections should be reviewed with comprehensive planning agencies to ensure compatibility and lack of conflict.

Owners of high-capacity wells (more than 70 gpm) must obtain DNR permits and are required by law to annually report the amount of water pumped from their wells to DNR. These reports can be used for the analysis of historical and present industrial and irrigation uses. Lists of high-capacity wells are available from DNR district offices and from the DNR Bureau of Water Supply in Madison. Estimating future water demands of these private-sector users is more problematic. Local planning agencies, UW-Extension offices, developers, and others might be able to suggest possible future developmental considerations. Information for planning irrigation and livestock water needs can be obtained from the UW-Extension county offices.

As part of the State Water Quantity Plan, the DNR Bureau of Water Resources is developing 20-year projections of water use by county and by basin for the entire state. The Army Corps of Engineers' MAIN 2 model (Municipal and Industrial Needs) is being used to determine current and future use in five-year increments. The data will be available from the Bureau of Water Resources at the end of 1987 (and is scheduled to be published as part of the State Water Quantity Plan in August 1988).

To better understand the distribution and relative importance of the various groundwater uses in a local area, a map should be prepared indicating the locations of different categories of uses. This spatial representation of water use might show particular uses, the magnitude of the uses, and other relevant information, such as seasonality of use. Figure 3 is an example of such a map.

In a water-rich state like Wisconsin there is comparatively little water-supply planning. However, as demands on ground and surface water supplies increase, Wisconsin may need to give additional attention to this area. Establishing a sound overview of local water use may not only help demonstrate the justification and need for a local groundwater protection effort, but could also be an important step in assuring adequate future water supplies at the local level.

Assessing Local Groundwater Quality

Documenting Groundwater Quality

In most of Wisconsin, quality is a more critical element in a groundwater protection plan than is quantity. The documentation of current quality conditions is essential for determining any future quality changes. Understanding groundwater quality makes it easier to identify existing and potential management problems. Two approaches can be used to document groundwater quality. The first approach is to chart quality changes over time within a designated study area. This approach is usually limited by the lack of a good historical data base. The second approach is to examine the quality geographically as it varies across the study area. Instead of looking for historical trends, we identify areas where groundwater quality is impaired and relate the extent of impairment to different land uses or sources of pollution.

The assessment of current quality can be done by comparing the available analyses to state and federal standards. Water quality standards are recommended "safe" limits for some chemical constituents and desirable limits for others. Current drinking-water and groundwater quality standards are described and listed in Appendix B. The DNR can be contacted on the current status of water quality standards.

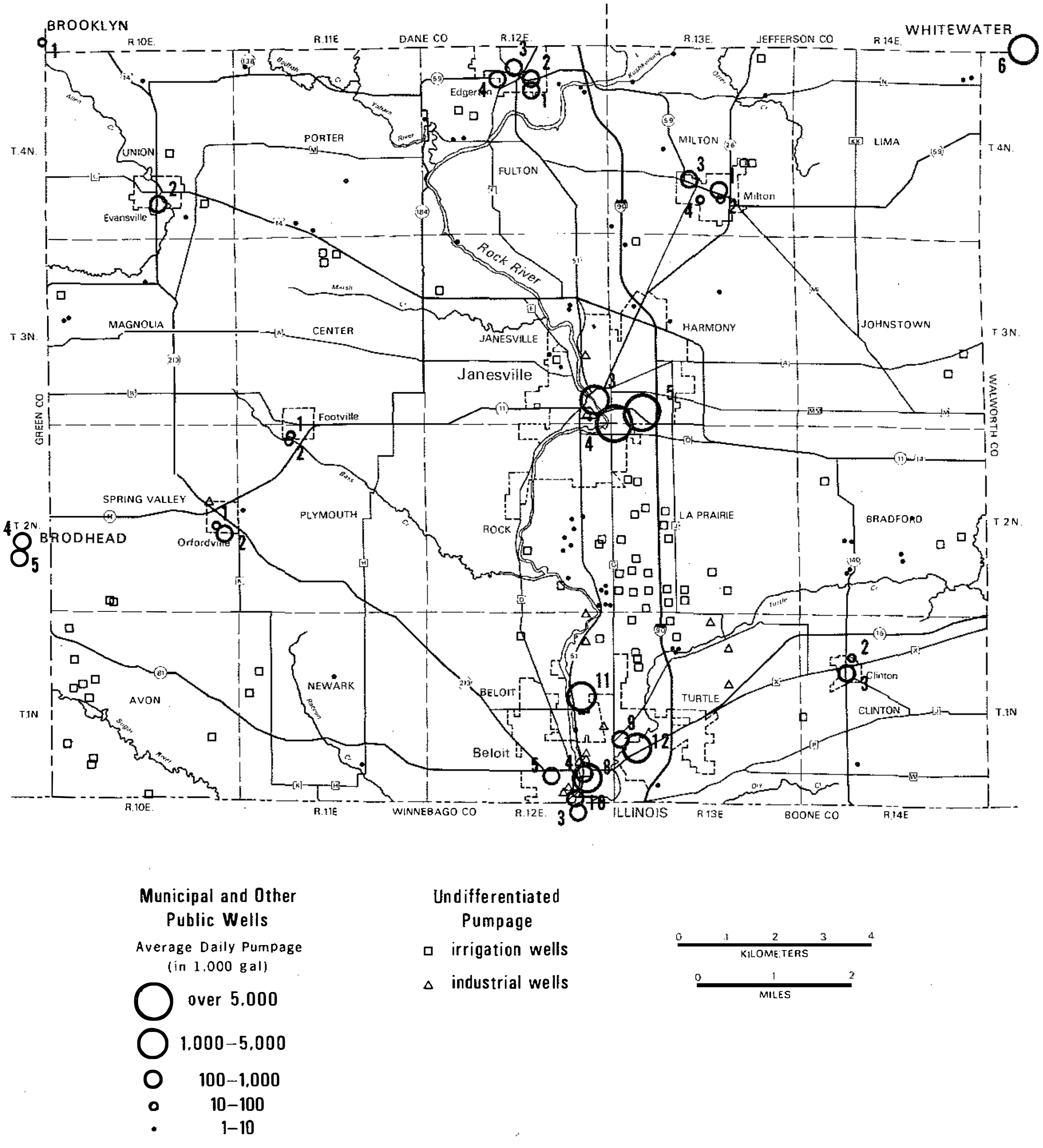


Figure 3. An example of a map showing major groundwater users (Rock County, 1979; from Zaporozec, 1982).

Groundwater quality information is usually available in some form, but may not have been compiled in a useful way unless previous water-supply studies have been done in the community. Therefore, groundwater quality data may have to be gathered as a component of the community groundwater protection planning.

Data Gathering

Published data provide an overview of groundwater quality in Wisconsin (Kammerer, 1981; 1984), but are rarely adequate for assessment of groundwater pollution from individual sources. Such pollution assessment requires design and installation of an effective monitoring and data collection program. Such a program may include the sampling of existing public and private wells, but data interpretation may be difficult if well depths and construction are unknown. Collecting groundwater quality data is a complicated and costly process in which local governments can have only a limited role. The services of a consultant and commercial laboratory are usually required. There are several ongoing monitoring programs that can provide information on local quality of groundwater, even though a special effort is sometimes required to locate the data. The DNR district offices and regional planning commissions can advise you on the availability of water-quality data in your county.

A large amount of groundwater quality data exists on computer file maintained by the U.S. Geological Survey (USGS). The USGS District Office in Madison collects and analyzes groundwater samples in conjunction with water-resource investigation projects. The chemical analyses generally include major constituents and properties of groundwater. More specialized analyses may also be performed, depending on the purpose and scope of the project.

The DNR monitors water quality of the community and noncommunity water systems that supply water to the public. The community systems are tested, during a 3- to 5-year period, for inorganic chemicals listed in chap. NR 109, Wis. Administrative Code and for coliform bacteria. They are also tested at least once every 4 years for radioactivity and once every 10 years for volatile organic chemicals (VOC). Noncommunity systems are tested for nitrate and coliform bacteria on a 5-year basis. The State Laboratory of Hygiene maintains a county-by-county file of nitrate analyses from private wells which they perform. The DNR Bureaus of Water Supply and Water Resources Management have extensive data files on groundwater quality. Local DNR district or area offices can provide information on what kind of data have been collected.

The Wisconsin Geological and Natural History Survey (WGNHS), in cooperation with Barron, Chippewa, and Dunn Counties, has been collecting and analyzing water quality samples for nitrate, chloride, total solids, and specific conductivity. The UW-Extension Environmental Resources Center and the Central Wisconsin Groundwater Center analyze samples for nitrate for interested citizens as a part of local educational groundwater programs. Information on water quality can also be obtained from some county and city health officials who collect chemical analyses of samples taken within their area and from the University of Wisconsin departments of Geology and Geophysics, Chemistry, and Soil Science.

Water-Quality Monitoring

If existing data are inadequate for planning purposes, it may be necessary to undertake a comprehensive groundwater sampling program to obtain suitable water quality information. Characterization of a site or area with respect to water quality requires a data collection network. Groundwater quality monitoring is used to characterize the groundwater quality of regional aquifers and to detect changes in quality over time and space. Monitoring networks are also designed to measure the effectiveness of protection controls, to provide evidence of legal compliance with the drinking-water and groundwater standards, or to act as an early warning system. Finally, monitoring is used around potential pollution sources to locate the extent of a polluted zone, to evaluate the threat of the source, and to aid in developing remedial action. We must emphasize that monitoring systems do not protect groundwater quality; they only measure groundwater quality.

Most of the monitoring in Wisconsin is done by the state or by operators of potentially polluting sources as required by the state. Local governments may usually play only a supplemental role in monitoring as noted in chapter VI. With the passage of Wisconsin groundwater legislation (chap. 160, Wis. Statutes) in 1984, DNR-sponsored groundwater monitoring has been greatly expanded. The DNR spent approximately $850,000 on groundwater monitoring efforts in 1986. About $230,000 was used to test public and private water supplies for VOCs, pesticides, and radionuclides. Funding for monitoring came from fees for fertilizer and pesticide sales, storage tank installations, sanitary permits, waste generators, septic-tank servicing, and land disposal.

Chapter IV.

POTENTIAL POLLUTION SOURCES

Introduction

Sources of groundwater pollution are many and varied. Some natural processes and most human activities can directly or indirectly contribute to groundwater quality problems. Since people are typically the agents of groundwater pollution, many of the groundwater pollution sources are found in and near population centers. The type, duration, and intensity of human activity will determine the degree of risk posed to groundwater quality. Field investigations, and in some cases very detailed studies, may be necessary to determine if potential pollution problems exist.

Many activities that can contribute to groundwater pollution are closely integrated into our economic and cultural way of life and may indeed be considered indispensable. Practices such as disposal of municipal sewage sludge and application of agricultural chemicals to increase crop yields are examples of such activities. Management strategies to reduce the impacts of these activities on groundwater quality will probably be aimed at modifying the practices rather than eliminating them.

A local government, in cooperation with specialists and technical advisors, must estimate the significance of each activity within its jurisdiction and estimate the relative risk to the health and well-being of its citizens and to the environment. Such estimates should represent an informed judgment based on factors such as the likelihood of groundwater quality impairment (chap. V), health effects of potential pollutants, and the associated risks (chap. VIII).

Results of the pollution source inventory should be tabulated and displayed on maps. Pollution sources should be located in the field, accurately referenced spatially, and then plotted on maps (see example on fig. 4). The scale of the maps should be compatible with the scale of other maps available for the planning effort. By displaying all planning information on maps at the same scale, the maps can be overlaid in various combinations. The pollution sources maps can be related, for example, to physical resource maps to evaluate the location of the pollution source with respect to its impact on the environment (see chap. V). Some local governments may employ computer technology to store and assess inventory data.

Inventory of Potential Sources of Pollution

The inventory of potential pollution sources is an essential step in developing local groundwater protection programs. This process can be tailored to the specific needs and resources of individual counties or municipalities. Ideally, information on all potential sources of pollution would be available. In reality, varying levels of data are available for different sources. For example, information on animal feedlots or chemical storage tanks can be gathered, but it may require more time and effort than is needed for other categories of sources. Local governments may tailor data gathering for the inventory to reflect local priorities and perceptions of problems. Thus, the inventory might focus on only a few potential sources initially, then update, expand, or add more detail at a later time.

Table 2 identifies potential groundwater pollution sources commonly found in Wisconsin and considered to have the most significant impact on the groundwater of the state. Sources are arranged according to their place of origin relative to the land surface. Potential pollution sources are not discussed in the order of their importance or significance, but are grouped into four general categories: waste disposal, agricultural activities, materials storage and handling, and other activities. Included for each

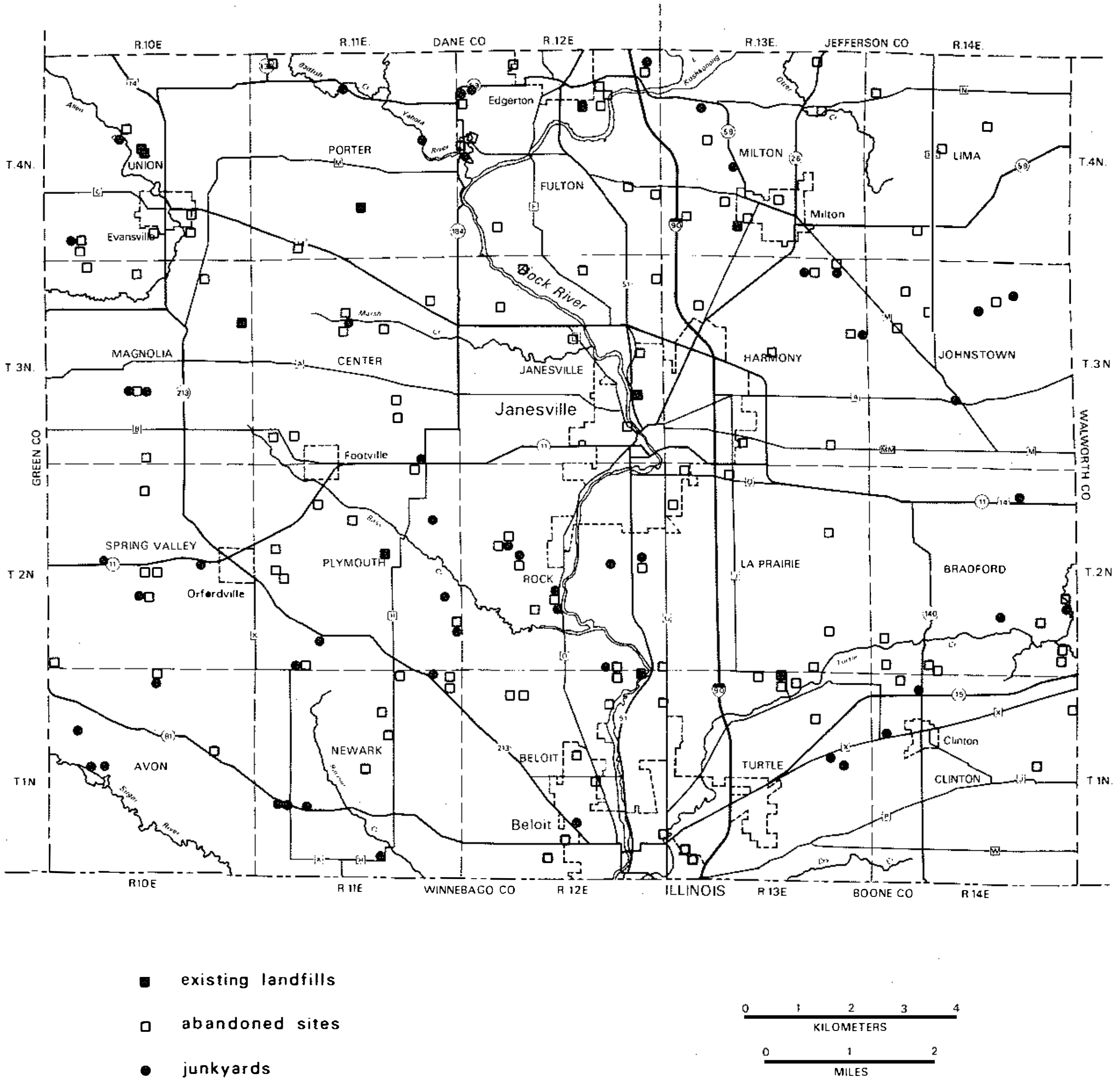


Figure 4. An example of a pollution source map. This map of solid waste disposal sites in Rock County was compiled from DNR inventory data at a scale of 1:100,000 and later reduced for the report (from Zaporozec, 1985).

potential source is a statement of the problem, a description of the source and pollutants produced from the source, an estimate of the relative significance of the source, and an indication of where inventory data is likely to be found.

Land Disposal of Solid Waste

Description of the Problem -- Solid waste disposal is an important potential groundwater pollution source. Continuous or intermittent contact between refuse and water produces an undesirable liquid called leachate. Landfill leachate is defined as a grossly polluted liquid characterized by high concentrations of dissolved chemicals, high chemical and biological oxygen demand, and hardness. Leachate composition is a function of the composition of the refuse and the volume of infiltrating water, and is extremely variable. It may also contain substances leached out from hazardous materials legally or illegally discarded at the site.

The threat to groundwater from waste disposal sites depends on the volume and nature of the leachate, the amount of moisture in contact with refuse, the type of earth material through which the leachate passes, and the hydrogeology of the site. Because Wisconsin lies in a humid climatic zone, most of its waste disposal sites will eventually produce leachate. Disposal site success depends on how leachate production and movement is prevented or minimized (for example, by engineering design, appropriate site location, or management practices).

Sources of Information -- Because landfills are regulated by the Wisconsin Department of Natural Resources (DNR), most of the inventory information is available from that agency. The DNR is organized with one central office in Madison, and six district offices. District offices are often further subdivided and administered through area offices. For information on solid waste facilities, first contact the solid waste coordinator at the appropriate DNR district office.

The DNR licenses all active landfills. Some active sites are converted from old dumps; others are new and designed to meet current DNR criteria. New disposal sites must be lined and equipped with a leachate collection system that channels leachate and runoff from the site into an impermeable holding area from which the liquid is removed for treatment. The DNR usually has the most information regarding the impact of landfills on groundwater for active landfills because groundwater monitoring is often required.

Abandoned landfills can pose a serious problem to groundwater quality. These sites were often poorly operated, contain unknown wastes, and may be located in areas considered unsuitable for solid waste disposal. Because of these factors, DNR has an ongoing inventory of abandoned waste disposal sites. A list of sites that cause or threaten to cause environmental pollution is scheduled to be completed by July 1987. Local officials should assist the DNR in gathering information on abandoned landfills and use this information in the preparation of their groundwater management plan.

Salvage Yards and Junkyards

Description of the Problem -- Until 1981 salvage yards/junkyards were licensed by the DNR as part of the solid and hazardous waste program. Well-operated junkyards handling hazardous automotive materials (such as grease, oil, solvents, and battery acid) minimize groundwater pollution problems. Although DNR authority to license junkyards was removed by the Wisconsin Legislature in May 1981, DNR continues to regulate hazardous materials at junkyards under the Hazardous Substances Spill Law (sec. 144.76, Wis. Statutes). If hazardous waste is present at salvage yards, the hazardous waste management rules (chap. NR 181, Wis. Administrative Code) would apply.

Sources of Information -- The DNR no longer maintains a comprehensive listing of salvage yards. However, the district solid waste coordinator should have access to the

Table 2. Activities that may create groundwater quality problems in Wisconsin

PLACE OF	POTENTIAL POLLUTION SOURCES			
ORIGIN	Municipal	Industrial	Agricultural	Other
Waste-related				
At or near the land surface	Sludge and wastewater disposal (N)		Feedlots (P) Manure storage (P) & spreading (N) Whey spreading (N)	Septage disposal (N) Junkyards (P)
Below the land surface	Landfills (P) Wastewater impoundments (P) Seepage cells (P) Sanitary sewers (L)		Manure pits (P)	Septic systems (P) Holding tanks (P)
Non-waste				
At or near the land surface	Salt piles (P)	Above and on the ground storage of chemicals (P) Stockpiles (P) Tailing piles (P) Spills (P)	Irrigation (N) Fertilizers (N) Pesticides (N) Silage (P)	Highway deicing (L) Lawn fertilizers (N)
Below the land surface		Underground tanks (P) Pipelines (L)		Improperly constructed & abandoned wells (P) Overpumping (induced pollution) (P)

Note: P=point source; N=nonpoint source; L=line source

1981 files and/or have files available on a specific site if a complaint has been received. A computerized listing of salvage yards in operation in 1981 is available from the DNR Bureau of Solid Waste Management, Systems Management Section. Other records may be available from local zoning office files.

Wastewater Disposal Systems

Description of the Problem -- The disposal of municipal or industrial liquid waste should be considered as a potential source of pollution. Most communities collect municipal and industrial wastes and treat them in sewage treatment plants before discharging the effluent. Typical waste from municipalities contains substances having biochemical oxygen demand (BOD), nitrate, and other pollutants that could enter the groundwater.

Some sewage treatment plants first use treatment lagoons for oxidization and settling, then seepage cells (absorption ponds), which allow the treated wastewater to filter into the ground. If properly sited, operated, and maintained, these seepage cells should not cause groundwater pollution. The retention time in the seepage lagoons is usually sufficient to ensure low levels of bacteria and viruses. Occasionally, however, nitrate, ammonia, sulfate, and heavy metals from the seepage cells reach the groundwater in significant concentrations. There is concern that municipal sewage also may contain industrial and household chemicals not removed in the lagoons.

Sources of Information -- The location of municipal and industrial treatment plants that discharge to groundwater should be identified and evaluated in a local groundwater management plan. The DNR areawide water quality management plans written for each river basin in the state should contain this information. The DNR Bureau of Wastewater manages data containing information on the location of such sewage treatment plants as part of the Wisconsin Pollutant Discharge Elimination System (WPDES) program. This program is decentralized and the district wastewater supervisor or water resource planner in the appropriate district office should be contacted for information. The request also may be forwarded to an area office.

Sanitary Sewers

Description of the Problem -- Many miles of sanitary sewers are located in cities, villages, and sanitary districts throughout Wisconsin. Infiltration of groundwater into sewers has been the subject of much investigation because excess flow can overload the sewage treatment plant. On the other hand, little attention has been paid to exfiltration (the leakage of sewage into the ground) because the resulting loss of flow is frequently ignored or considered an asset by the treatment plant operator. From a groundwater pollution standpoint, however, exfiltration can be a problem in some areas. Pollutants of concern include nitrate or other forms of nitrogen, bacteria, and any hazardous materials that may have been introduced into the sewer.

Leaking sanitary sewers are probably not a major source of groundwater pollution in most of Wisconsin. Although pressure sewers and force mains have a greater potential for exfiltration than gravity sewers, more often than not, groundwater leaks into sewers rather than sewage leaking out.

Sources of Information -- Records of the community that has the sewers is the best source of information regarding the location of sewer lines and flow through the sewers. The wastewater treatment plant should have records that identify the flow into the plant and should also have information on what the expected flow should be. Therefore, whether there is exfiltration or infiltration into the sewer lines can be determined. However, because of the relative insignificance of sewers as a potential groundwater pollution source, this is probably not an efficient use of time--except in the areas of highly permeable soils and shallow bedrock. Some information regarding hazardous waste discharged to sanitary sewers can be found at DNR in the annual hazardous waste reports received from hazardous waste generators.

Private Wastewater Systems

Description of the Problem -- Private wastewater systems are used to dispose of household wastes. A conventional private wastewater system consists of a septic tank (a water-tight tank placed underground) and soil absorption field. Household wastes are discharged from the house into the tank, where most solids (called sludge) fall to the bottom of the tank and are partially digested by bacteria. In a properly operating system, the liquid waste (called septic tank effluent) flows from the septic tank to the soil absorption field where harmful bacteria are removed as the effluent moves through the soil. However, viruses and hazardous substances may not be eliminated. Pollutants of concern from septic system discharges are nitrate, bacteria, viruses, and hazardous substances. Even in properly functioning septic systems, some nitrate is discharged to the groundwater, and closely spaced septic systems may contribute nitrate in excess of the groundwater standard of 10 mg/l of NO_3-N. A concentration of septic tanks in a marginally suitable environment could create a significant groundwater pollution problem.

If the soil is highly porous or very thin, groundwater pollution is more likely to occur. Serious problems can occur when septic systems are placed in sand-and-gravel deposits with a shallow water table or in areas with creviced bedrock near the land surface. In such cases effluent can reach the groundwater virtually untreated.

Sources of Information -- It is difficult and time consuming to inventory all private wastewater treatment systems in an area. A more generalized approach would be to locate unsewered communities, since these would represent concentrated areas of septic-tank use. Unsewered communities include, for example, mobile home parks and subdivisions without sewer hookups. They are identified in areawide water-quality management plans, as prepared by the DNR or other planning agencies. The plans are to be updated every 5 years. The DNR district water resources planner or a regional planning agency should be contacted for this information. The Department of Industry, Labor and Human Relations (DILHR) licenses all private wastewater systems greater than 3,000 gallons and can provide a listing of these systems.

Sludge and Septage Application

Description of the Problem -- Sludge is an organic, non-sterile by-product of treated wastewater. It is composed mostly of water (up to 99 percent of its weight) and organic matter. Industrial and municipal sludge may contain hazardous chemicals and metals removed during the wastewater treatment process. Metals often found in sludge at variable concentrations include arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc. The type and concentration of metals found in sludge depend on the source of the wastewater. Most of the metals in sludge come from industrial sources. Other constituents of sludge that may have an impact on groundwater are nitrogen compounds, chloride, and pathogenic bacteria and viruses.

Pollution from land application of municipal sludge depends on the concentration of pollutants in the sludge, application rate, physical and chemical soil properties, amount of precipitation, and distance to the water table. Coarse-textured soils, a shallow water table, and high rates of precipitation increase the likelihood of groundwater pollution.

Septic tank pumpings, commonly referred to as septage, are a mixture of sludge, fatty materials, and wastewater. They may contain significant amounts of pathogenic organisms, nutrients, solvents, and oxygen-demanding material. Landspreading is the most frequently used septage disposal method.

Sources of Information -- DNR district offices have listings of authorized municipal and industrial sludge disposal sites. They regulate the disposal of sludge onto croplands to match the nutrient loading to the crop needs. Sludge with nonbeneficial uses cannot be landspread. DNR inspects the proposed site for land application before it issues the permit. DNR also has information on septage disposal sites, but this may not be current. Chapter NR 113, Wis. Administrative Code, which applies to land disposal of septage, is currently being revised and will probably become effective by the fall of 1987. This rule would require application to DNR for existing as well as new sites and would result in an up-to-date list for each county.

Animal Feedlots

Description of the Problem -- Feedlots, loosely defined as outdoor areas where animals are concentrated for feeding or other management purposes, are common in Wisconsin. The principal pollutants associated with feedlots are nitrogen, phosphorus, chloride, oxygen-demanding material, and microorganisms. Feedlots can also be a source of objectionable odor and taste in the water.

Sources of Information -- Information on the location and size of animal feedlots include the Department of Agriculture, Trade, and Consumer Protection (DATCP) livestock waste management plans and DNR Priority Watershed Plans. In counties where these plans do not exist, staff of the county land conservation committee, Agriculture Stablization and Conservation Service, and the UW-Extension can provide the best information. Large animal feeding operations are regulated under the WPDES program for point source dischargers (chap. NR 243, Wis. Administrative Code). All feedlots with more than 1,000 animal units (an animal unit is equal to 1,000 lbs of animal weight) must apply for and receive a discharge permit before they can operate. The DNR Bureau of Wastewater can be contacted for a listing of those feedlots. If complaints are made against smaller animal feedlots, DNR and DATCP staff inspect the site. Records of the inspections are kept in DNR and DATCP files.

Livestock Waste Storage

Description of the Problem -- Livestock waste produced, stored, and disposed of on dairy, beef, hog, sheep, and poultry farms is a potential source of groundwater pollution. The primary pollutants are nitrate, chloride, and bacteria. High levels of livestock waste pollution may also cause discoloration, odor, and taste problems in drinking-water supplies and, in extreme cases, bacterial contamination. In general, properly designed, located and managed livestock storage facilities have little potential for causing significant groundwater pollution. However, improperly designed and located or poorly managed facilities can create problems.

Sources of Information -- If adequate inventory information is not available from one of the sources discussed in the previous section, several options remain. The Wisconsin Agricultural Statistical Reporting Service keeps records on the numbers and types of livestock within each county. Total volumes of livestock waste generated within a county can be determined by estimating waste generated from the livestock numbers identified. It may be necessary to survey landowners to identify how livestock waste is managed within feedlots or to gather specific information. County land conservation committee and SCS staff, as well as staff from the County Extension Office, can facilitate the collection of this county inventory data. County Agricultural Stabilization and Conservation Service (ASCS) records may provide detailed information on the location and number of dairy animals within the county. This information may also be found in the priority watershed plans.

Landspreading of Livestock Waste

Description of the Problem -- The following practices can lead to groundwater pollution from landspread livestock waste: 1) spreading livestock waste at rates that exceed crop nitrogen needs, 2) not crediting nitrogen from livestock waste when calculating crop fertility needs, or 3) locating water wells where surface runoff can transport wastes to the well (polluted runoff may infiltrate along the well casing if the casing is not properly grouted).

Sources of Information -- The sources of inventory information discussed under livestock waste storage also pertain to landspreading of livestock waste.

Fertilizer Application

Description of the Problem -- Commercial fertilizers include a variety of types and concentrations of nitrogen, phosphorus, potassium, and trace elements. While nitrogen and phosphorus may contribute to eutrophication of surface waters, it is the nitrogen component of fertilizer that is of greatest concern for groundwater. When nitrogen-based fertilizer is applied in excess to agricultural land, a portion of the fertilizer usually leaches through the soil. However, even normal application necessary to achieve economic yields can result in some leaching of nitrate to the groundwater, particularly in sandy soils and may lead to groundwater pollution in the form of nitrate.

Sources of Information -- The Wisconsin Agricultural Statistical Reporting Service maintains records by county on the number of acres of each crop grown in Wisconsin. County ASCS offices have detailed records of crops grown on farms participating in government feed-grain programs. Fertilizer needs and rates depend greatly on soil type, previous cropping history, and yield objectives of individual growers. Although the variance and annual change in fertilizer rates makes it difficult to collect site-specific data, information on typical rates used for crops grown in different areas of the state on a variety of soil types is available from county UW-Extension offices. This information can be used to estimate total nitrogen applied in a specific county or area. To determine total nitrogen, multiply the number of acres of a crop grown by the typical fertilizer application rate used for that crop in that area. If more specific information is needed it will be necessary to conduct a door-to-door survey of landowners to obtain specific application rates on a field-by-field basis.

Pesticide Application

Description of the Problem -- Pesticides are widely used in Wisconsin for insect and weed control in crop production. Although no data indicate their widespread presence in groundwater at this time, certain pesticides have been detected in some areas of the state, for example aldicarb in the Central Sands area. If applied properly, most approved pesticides are generally taken up by plants or broken down to harmless substances by soil organisms, sunlight, or chemical reactions and do not usually threaten groundwater. The greatest potential for pollution from field-applied pesticides exists in irrigated sandy soils or in areas where thin soils overlay creviced bedrock. Infiltration rates are rapid in sandy soils and some pesticides do not have enough time to be inactivated before reaching the groundwater. Pesticides attached to sediments may flow directly to the groundwater through cracks in dolomite (or limestone) and add to groundwater pollution. Accidents or improper storage, handling, and transport of pesticides can be a source of significant localized groundwater pollution.

The pollutants that may result from pesticide application are the pesticides themselves or their breakdown products. Pesticides include a wide array of chemical types but generally fall into three broad categories: chlorinated hydrocarbons, organo-phosphorus, and carbamate pesticides (these are the most water soluble). DATCP can supply specific information regarding pesticides of concern.

Sources of Information -- The Wisconsin Agricultural Statistics Reporting Service in Madison published the first pesticide use report in 1986. This report details the types and amounts of pesticides used for different crops in Wisconsin during 1985. The percentage of pesticide use for a given crop can be determined from this statistical report. This information could be used to estimate the total amount of a given compound applied in a given area. To do this, the number of acres of crops on which the pesticide is used must be determined. This acreage is then multiplied by the percentage of growers who normally use that pesticide and the average rate of application. This will provide an estimated total of the amount applied. If more detailed information is needed it will be necessary to survey farmers within specific areas. DNR has information on the results of pesticide monitoring in the state.

Irrigation

Description of the Problem -- Irrigation can contribute to groundwater pollution in two ways. Irrigation water may leach potential pollutants (land-applied fertilizers and pesticides) to the groundwater. Overirrigation may worsen this problem. In addition, chemicals are commonly applied through the irrigation systems. If the required back-flow preventors are not installed and maintained, these chemicals may flow back into the well and enter the groundwater system.

Sources of Information -- The DNR Bureau of Water Supply approves all high-capacity wells in the state. Information on irrigation wells, including their location and pumpage rate, can be obtained from the DNR Bureau of Water Supply, Private Water Supply Section. The DNR Private Water Supply Section also has information regarding farmers who apply fertilizers and/or pesticides through irrigation systems. These farmers must install back-flow preventors on their irrigation systems and notify DNR when they are installed.

Hazardous Materials Storage

Description of the Problem -- Many hazardous substances and hazardous wastes are part of our everyday agricultural, commercial, and domestic activities. Improper storage, handling, or disposal of these materials can lead to serious pollution problems if they infiltrate the groundwater. "Hazardous materials" is used here as a broad term that includes both "hazardous wastes" and "hazardous substances."

A hazardous waste is a material that is intended to be discarded or is no longer usable for its originally intended purpose. A waste may be subject to regulation because the law specifically lists it as hazardous or because it exhibits a hazardous characteristic (i.e., ignitable, corrosive, reactive, or toxic) described by the law. The specific requirements for its treatment, storage, disposal, transport, and reporting vary depending upon how much waste is generated. There are four categories of waste generators: 1) less than 1 kg of acutely hazardous waste per month; 2) less than 100 kg of hazardous waste per month; 3) 100 to 1,000 kg per month; and 4) more than 1,000 kg per month. Generators of smaller quantities are regulated less stringently than large-quantity generators. Hazardous waste from households is not regulated and may be disposed of in a sanitary landfill.

"Hazardous substances," as defined by Wisconsin law, are materials that pose a substantial present or potential hazard to human health or the environment. Hazardous substances are not as broadly regulated as are hazardous wastes. There are some requirements on their labeling and transporting. There are no regulations for the storage of many hazardous substances, such as certain solvents, thinners, and cleaning fluids, even though they are regulated once they become a waste through a production process. Still, other hazardous substances are partly regulated. The DATCP rules for bulk storage of fertilizers and insecticides apply to all manufacturers and distributors but not to end users such as farmers. The rules set standards for storage containers, loading areas, secondary containment, record keeping, inspection, and an emergency response plan. The DILHR underground petroleum storage tank program is discussed below, and the DNR hazardous substances spill program and the DOT salt storage program are discussed further on.

Sources of Information -- Information is available from DATCP on the location and other details about storage sites for bulk fertilizers and pesticides. DNR has information on the amounts and types of hazardous waste being handled at specific locations throughout the state through the shipment tracing system (manifest) and annual and quarterly reporting systems. The federal Superfund Amendments and Reauthorization Act of 1986 (SARA) created community right-to-know reporting requirements which, when they are implemented, will require a manufacturer to submit information about hazardous chemicals to state and local governments, including the local fire department.

Chemical Storage Tanks

Description of the Problem -- Storage and transmission of a wide variety of fuels and chemicals is inherent in many industrial, commercial, and individual activities. Petroleum and petroleum products are the most common potential pollutants. Throughout Wisconsin, underground gasoline and oil storage tanks installed during the 1950s and early 1960s have now reached or exceeded their expected 20- to 30-year life span. Some have begun to leak and pollute the groundwater because they were not constructed of corrosion-resistant materials. Leaks in buried tanks and pipelines at industrial facilities are a particular problem because they may go unnoticed for some time. Gasoline is less dense than water and generally floats on the groundwater surface, and fumes may penetrate into basements, sewers, wells, and springs, rendering drinking water unsafe and creating explosion and fire hazards.

The large volume and high concentration of hazardous materials that can be released from a storage tank in a small area create a high on-site pollution risk. Leaks may not be detected until a large amount of chemical has been released. The majority of chemical tanks are in urban areas on main roads within municipalities, and thus, relatively close to public water-supply wells.

Sources of Information -- The DILHR Bureau of Fire Prevention regulates underground petroleum product storage tanks. It has inventoried all abandoned tanks and large operational tanks in the state as mandated by new state and federal laws. Since this is a new program for DILHR, the inventory has not been completed and how it will be distributed has not been determined. The information being collected as part of the inventory includes tank age, construction, size, location, and material stored in the tank. Information proprietary in nature will also be collected, but may not be available on demand.

Spills of Hazardous Substances

Description of the Problem -- The number of reported spills in Wisconsin continues to increase--from 675 in 1984 to 785 in 1985 to 1,023 in 1986. An undetermined number of additional spills and illegal dumpings go unreported. Petroleum products are the pollutants most commonly spilled. Spills can occur anywhere at any time; on site or off site; on highways, runways, waterways, or railroads. Fortunately, many spills are small and can be cleaned up quickly before much of the substance reaches the groundwater.

The number of hazardous spills indicates that existing preventive controls are not sufficiently protecting groundwater. Wells adjacent to spills are at high risk for groundwater pollution if spills are not promptly and thoroughly cleaned up. If some of a spill reaches the groundwater, the cost of remedial action (if feasible) can be very high.

Better management of facilities and equipment used for storage of hazardous substances, careful transport of hazardous materials, and immediate handling of spills by trained individuals can help minimize the risk of polluting groundwater.

Sources of Information -- The DNR Bureau of Solid Waste Management, Hazardous Waste Management Section Spill Coordinator in Madison maintains an inventory of hazardous substances spills reported to DNR and its district offices. Section 144.76(2), Wis. Statutes, and chap. NR 158, Wis. Administrative Code, require all spills of hazardous substances be reported to DNR or to a designated 24-hour hotline number. The inventory, computerized and available upon request, includes: date of incident, primary substance, quantity of substance, location of incident, destination of spilled substance, the cause of spill, and spiller's identity. In addition, the DNR Bureau of Solid Waste Management keeps a log of abandoned containers that may present potential problems.

Storage and Use of Salt for Road Deicing

Description of the Problem -- Salt storage, road salting, and snow disposal may result in high salt concentrations in both ground and surface water. Salt storage in uncovered piles appears to contribute most to groundwater pollution. Precipitation can dissolve salt that may then infiltrate shallow aquifers. High salt concentrations in drinking water are a health concern to anyone restricted to a low sodium diet.

Salt used for highway deicing is less important as a source of groundwater pollution in rural areas than in urban areas. Storage sites for road salt should be designed to reduce surface water runoff and minimize salt infiltration to the groundwater. Storing salt in shelters and barns is not only economically sound, but helps prevent groundwater pollution.

Sources of Information -- The Department of Transportation (DOT) regulates the use and storage of road salt used to deice state highways. DOT has an inventory of storage locations throughout the state and has developed design standards for salt storage areas.

Abandoned and Improperly Constructed Wells

Description of the Problem -- Water wells, under certain conditions, can be conduits for groundwater pollution. For example, wells with casing that has been corroded or ruptured and wells in which the surface casing has not been adequately sealed allow pollutants from the land surface to enter the well. Improperly abandoned wells that have not been plugged also threaten groundwater because they permit water containing pollutants to migrate freely from one aquifer to another or from the land surface to an aquifer. They may be a major problem in localities where public water systems have been installed after the area was developed with private wells.

Sources of Information -- Wells no longer in use are required to be properly abandoned. Only licensed well drillers may abandon unused wells. They must complete a well abandonment form and submit that form to the appropriate DNR District Office. The well abandonment program and the forms, however, have not been closely monitored by the district staff until recently. A new administrative rule (chap. NR 145, Wis. Administrative Code) authorizes the DNR to delegate responsibility for implementation of the private well code (chap. NR 112, Wis. Administrative Code) to counties. Participation by counties would be on a voluntary basis. The first level of county participation in this program would enable counties to conduct pre- and/or post-well installation and abandonment inspections to ensure that requirements are carefully followed. Standard forms, granting access to the location and other important information regarding the wells, would be made available for use by the counties. Chapter NR 111, Wis. Administrative Code, requires municipalities to adopt and enforce local well abandonment ordinances. Information on local well abandonment programs can be obtained form local water utilities and the DNR.

Chapter V.

ENVIRONMENTAL ASSESSMENT

Processes and Factors Affecting Pollutant Fate and Transport

The physical environment may provide some degree of natural protection with regard to pollutants entering groundwater. Thus, evaluating the physical environment and its ability to attenuate entering pollutants is an integral part of any sound groundwater protection program. The degree of attenuation that occurs between the source of pollution and the aquifer determines the potential for groundwater pollution. The attenuation of most pollutants as they travel through the unsaturated zone and groundwater system depends on a variety of naturally occurring chemical reactions and biological and physical processes that can alter the pollutant's physical state or chemical form. These changes may decrease the severity of pollution or quantity of pollutants. When pollutants reach the saturated zone (an aquifer), there are fewer mechanisms to attenuate pollutant concentrations.

The degree of attenuation depends on 1) grain size and physical and chemical characteristics of the material through which the pollutant passes, 2) time the pollutant is in contact with the material through which it passes, 3) distance that a pollutant has traveled through the unsaturated zone (Aller and others, 1985), and 4) physical and chemical characteristics of the pollutant. In general, the longer the time and the greater the distance traveled, the greater the potential for attenuation. Similarly, the greater the surface area of the material through which the pollutant passes, the greater the effect of attenuation.

Knowledge of soils, geologic materials, and the groundwater system is essential to evaluate the attenuation capacity of the environment. Soil is the first layer encountered by infiltrating water or entering pollutants. Among the most significant factors determining the rate and extent of groundwater recharge and the degree of natural protection against pollution are soil characteristics (slope, depth, texture, and permeability). In the soil zone, biological processes effectively remove a large number of human-introduced chemicals. The root zone has the greatest variety and magnitude of biological activities. It is in the root zone that significant amounts of chemicals are broken down by microorganisms or chemical and physical processes and then taken up by plants. Activities in this zone determine how much material will be available for potential leaching to groundwater.

The character of earth materials--especially the size and interconnection of the openings through which water passes--is important to the pollution attenuation process. Fine-grained materials are, in general, more conducive for attenuation processes than coarse-grained materials. Clay is effective in removing pollutants because its pores are small and its particles have great capacity for adsorption and ion exchange. Significant amounts of pollutants are removed as water moves slowly through the clay, silt, and sand of glacial till. In some places, however, water can form channels through the till material. If pollutants enter these channels, water may become highly polluted for relatively long distances. Materials with large openings, such as coarse sand or gravel, permit pollutants to advance rapidly without reducing their concentrations. Groundwater in fractured bedrock (e.g., dolomite) can be easily contaminated because pollutants are shunted into the aquifer along cracks, fractures, and solution channels.

Depth to water is important because greater attenuation can occur with a longer passage through the unsaturated zone. In some cases pollutants will enter the groundwater regardless of how favorable the environmental factors are. When this occurs knowledge of the direction and rate of groundwater flow becomes an important means of predicting the fate of pollutants in the aquifer and determining the threat to groundwater users down-flow from pollution sources. Details on factors influencing groundwater movement can be found, for example, in Heath (1983).

Information Sources About the Physical Environment

Physical resource information is gathered by several agencies for different purposes. In Wisconsin, the Wisconsin Geological and Natural History Survey (WGNHS), the U.S. Geological Survey (USGS), and the U.S. Soil Conservation Service (SCS) collect and disseminate information on geology, water, topography, or soils needed for the evaluation of the physical environment. In addition, some local and regional planning agencies collect and analyze environmental resource data. The Central Wisconsin Groundwater Center (CWGS) is another source of information for that area of the state. The WGNHS and the USGS also participate in cooperative projects with local governments to help them obtain technical information needed for the development of groundwater protection plans. The information used in evaluating the environment and sources of such information are listed in table 3.

The logs of water wells can provide valuable information. Well drillers have been required to submit drilling reports on DNR forms since 1935. Besides the thickness and character of unconsolidated sediments and type of bedrock, well drillers' reports provide information on water levels and water yields. Extensive files of well drillers' reports are maintained by the Private Water Supply Section of the DNR Division of Environmental Standards in Madison. Copies of the reports are also on file at the WGNHS. Many of the wells, especially those with high yield, have been geologically documented. Approximately 6,300 geologic logs are on file at the WGNHS in Madison. Supplemental information can be obtained from local well drillers.

County planners and officials will need better knowledge of the distribution and composition of surficial deposits before rendering site-specific recommendations in a county groundwater protection plan. As table 3 points out, some of the data currently available are inadequate for a detailed evaluation of the physical environment. Specifically, data on the bedrock and surficial geology at a scale of 1:100,000 are available only for a few counties. Hydrogeologic data are often insufficient or lacking. There is a good understanding of the hydrogeology in some counties, but for others such information is fragmentary or missing (fig. 5). In most cases hydrogeologic studies will be needed to make more detailed assessments of groundwater conditions. Appendix C contains a list of agencies that can provide groundwater-related information.

Systems for Evaluating Groundwater Vulnerability to Pollution

An Overview

Not all land use activities pose the same pollution threat to the groundwater resource and different parts of the environment have varying capacities for dealing with pollutants. Many methodologies have been developed to evaluate the groundwater pollution potential of existing or planned facilities and activities (particularly land disposal of wastes) or the vulnerability of the environment to pollution. There are a number of methods for evaluating groundwater pollution potential that can be applied to site-specific situations.

During the early 1960s it was recognized that groundwater pollution is a regional problem and that new methods were needed to evaluate the pollution potential of sites where wastes are released to the ground. Initially, methods were developed to evaluate the pollution potential of solid waste disposal sites or the sensitivity of various geologic environments to landfilling. This pioneering work was primarily done by LeGrand (1964) and the Illinois State Geological Survey, which in 1969 initiated a county series of geology-for-planning reports that classified the susceptibility of geologic settings to pollution from waste disposal. Among currently used methods, the most well known are the LeGrand system (LeGrand, 1980) for evaluating pollution potential from a given disposal site and the Mitre model. The Mitre model is a hazard ranking system used by the U.S. Environmental Protection Agency (EPA) to rank the severity of pollution problems at uncontrolled hazardous waste sites.

Table 3. Data needed for evaluation of the physical environment

Data needed	Source of data
SOILS	
Soil map	Soil survey maps 1:20,000 - SCS
Soil material and its properties:	Soil interpretation sheets - SCS
surface and subsoil texture	"
permeability	"
pH	"
content of organic matter	"
Drainage characteristics	"
Depth of the solum	"
Soil attenuation capacity	Map 1:100,000 - WGNHS (available only for some counties)
SURFICIAL GEOLOGY	
Glacial deposits	General map 1:500,000* - WGNHS
Type of material	General description
Permeability	Inferred from general description
Thickness	Map 1:1,000,000*
BEDROCK GEOLOGY	
Geologic map	Map 1:1,000,000* - WGNHS
Type of material	General description
Permeability	Inferred from general description of rocks
GROUNDWATER	
Depth to groundwater	WGNHS and USGS reports and files (not available for all counties)*
Groundwater elevation	
Slope of the water table	
Direction of groundwater flow	
Components of groundwater flow (recharge and discharge areas)	
Water quality	WGNHS, USGS, DNR, and CWGS files

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* Some counties have maps at scale 1:100,000; a list is available from WGNHS.

The methods vary greatly, depending on objectives of various regulatory agencies, the wide range of hydrogeologic conditions, and the degree of training and professional experience of hydrogeologists and other evaluators. The systems are technically complicated and can be expensive. Methods typically focus on a numerical index to denote the degree of groundwater pollution potential. Some methods, however, encourage the grouping or ranking of pollution potential without extensive usage of numerical indicators. The methods typically use several factors to evaluate the physical characteristics of the environment--most commonly, earth materials characteristics and depth to water and bedrock.

Land suitability analyses are areal evaluations to determine suitability of an area for specific uses. Land suitability mapping has become a standard part of planning analysis at many scales (Hopkins, 1977). A suitability map shows the geographical distribution of requirements, preferences, or predictors of some activity. A suitability map for vulnerability to pollution shows the pattern of characteristics that indicate varying degrees or likelihoods of pollution potential from some action. In 1985, a methodology called DRASTIC was developed for evaluating the pollution potential of hydrogeologic settings in the United States (Aller and others, 1985) and was tested in Portage County, Wisconsin (National Water Well Association, 1985). This system uses seven factors and is based on a ranking scheme that depends on a combination of weights and ratings to produce a numerical value. The numerical value is then used to help prioritize areas with respect to groundwater pollution vulnerability. The Wisconsin Department of Natural Resources has developed a computer-based system for evaluating

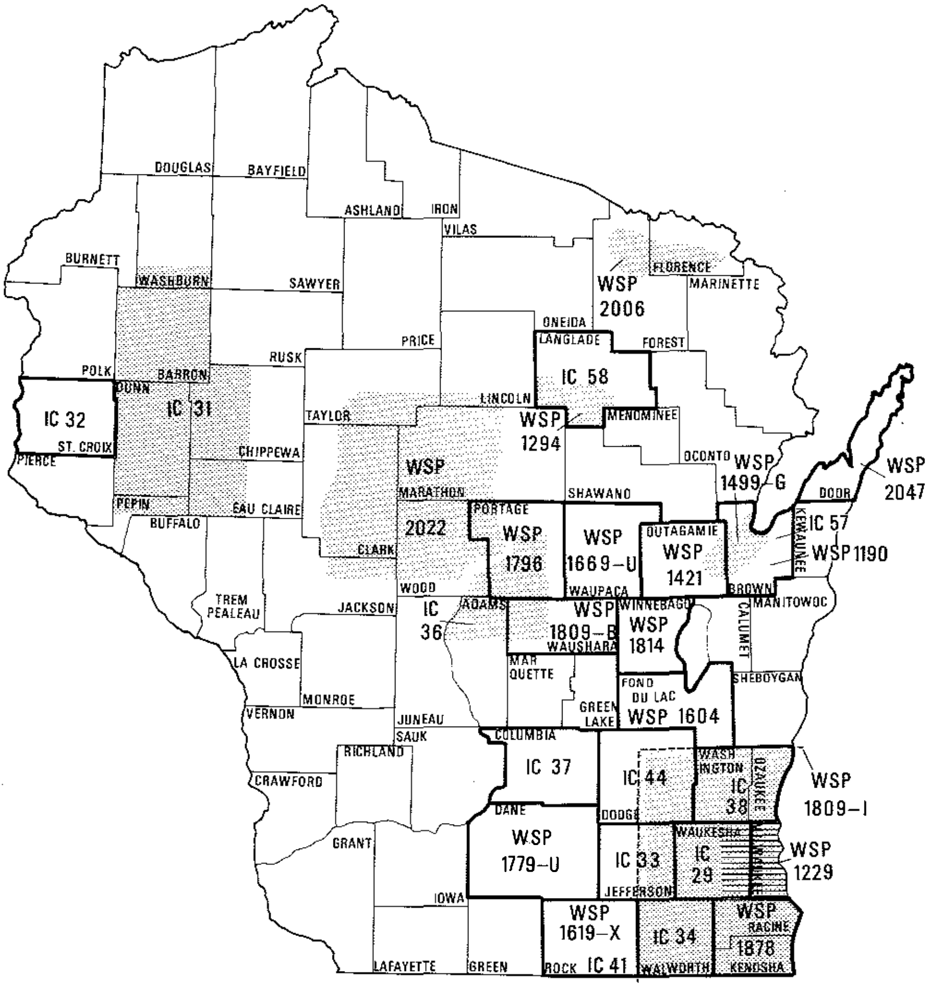


Figure 5. Published regional and county hydrogeologic studies (WSP = Water-Supply Paper, published by the U.S. Geological Survey; IC = Information Circular, published by the Wisconsin Geological and Natural History Survey).

the groundwater pollution potential at a statewide level on the basis of five factors: soil characteristics, surficial deposits, bedrock type, depth to bedrock, and depth to water table (Schmidt, 1987).

The evaluation systems provide a structured procedure for assessing pollution potential and for planning monitoring programs with a minimum of data. The systematic classification of pollution potential and the delineation of vulnerable areas provide a technically defensible basis for zoning and other regulatory measures. These methods require technical expertise and professional judgment. Although most Wisconsin counties probably will not have all the resources required for vulnerability mapping, they can obtain the services of specialists to assist them in completing an environmental assessment for their area.

A County Vulnerability Mapping System

This section describes a simple, easy-to-use system that is based on available information, which can be used by individuals with a diversity of backgrounds and levels of expertise. As previously mentioned, there are other similar mapping systems using many of the same factors. The system described here was developed by a team of specialists for a groundwater protection program in Rock County (Zaporozec, 1985). A similar approach, modified by a grid system with assigned numerical ratings, has been adopted by the Dane County Regional Planning Commission (DCRPC) in developing a groundwater protection plan. The system is not unique; it is a workable, mid-range' evaluation system that incorporates elements and approaches of other systems and adopts them for specific county conditions.

It differs from many other systems by 1) relying largely on qualitative rather than quantitative ranking and 2) relating the final composite maps to the location of the potential pollution sources. These sources are classified as those located at or near the land surface as compared to those at greater depths. Vulnerability mapping is divided into three separate components, depending on the intended use or activity and on the fate of pollutants in the subsurface:

1) evaluation of the attenuation capacity of soils,
2) evaluation of the attenuation capacity of subsurface materials, and
3) evaluation of the direction and rate of groundwater flow.

The separation into three components also allows the system to be selectively applied to evaluate potential pollutants at their place of origin.

The first component deals only with the evaluation of the ability of soils to attenuate pollutants resulting from pollution sources on the land surface or within the soil zone (about 3 to 5 feet below the surface). Soils are the top layer (the first line of defense) which the infiltrating water or entering pollutants encounter and they strongly influence the rate and extent of groundwater recharge and the degree of natural protection against pollution.

There are several options for assessing the potential of soils to attenuate pollutants. The most common approach is to use existing classification and soil maps produced by the U.S. Soil Conservation Service (SCS). Information needed for this assessment can be taken from county soil survey reports published by the SCS (fig. 6). For the Rock County study, the SCS approach was modified to better reflect the physical and chemical characteristics of soils involved in the attenuation process (Zaporozec, 1985). Seven physical and chemical characteristics were selected for each soil series and given weighted values: soil texture of the surface (A) and subsoil (B) horizons, organic matter content, pH of the A horizon, depth of soil solum (thickness of A and B horizons), and permeability. Soils with similar total point scores were then grouped into several soil associations, which, in turn, reflect differing attenuation potentials. Soil attenuation capacity maps are available for counties in which the WGNHS conducted water-quality studies (Barron, Chippewa, Dunn, Rock, and other counties).

The second component evaluates the ability of subsurface materials to attenuate pollutants resulting from activities below the first 5 feet or to attenuate pollutants that were not removed in the soil zone. The composition and succession of subsurface materials, and especially the permeability and thickness of unconsolidated deposits, determine the time and distance pollutants have for attenuation. Subsurface materials constitute the second line of defense. The evaluation of the relative attenuation capacity of the subsurface is based on the permeability of rock materials (consolidated and unconsolidated) and on the depth to bedrock and groundwater. Because data on subsurface permeabilities usually are lacking, the rock types (dolomite, sandstone, till, and sand and gravel) can be used to estimate permeability ranges. These subsurface parameters are easily obtained and generally represent all the important aspects of pollution attenuation (dilution, adsorption, transport distance, etc.). However, their interpretation requires substantial professional judgment.

Components 1 and 2 of the evaluation system rely on a protection strategy--on the ability of the soil and subsurface materials to attenuate pollutants. Nevertheless, pollutants sometimes enter the groundwater and move with it as it flows. In these cases, the third component--determining the direction and rate of groundwater flow--becomes important in predicting the fate of pollutants in the aquifer and determining the threats to groundwater users down flow from pollution sources. This third component of the evaluation system does not provide any defense against pollutants, but it is an important tool for evaluating the movement of pollutants within the groundwater flow system. It can also be helpful in defining protection districts around significant water-supply wells.

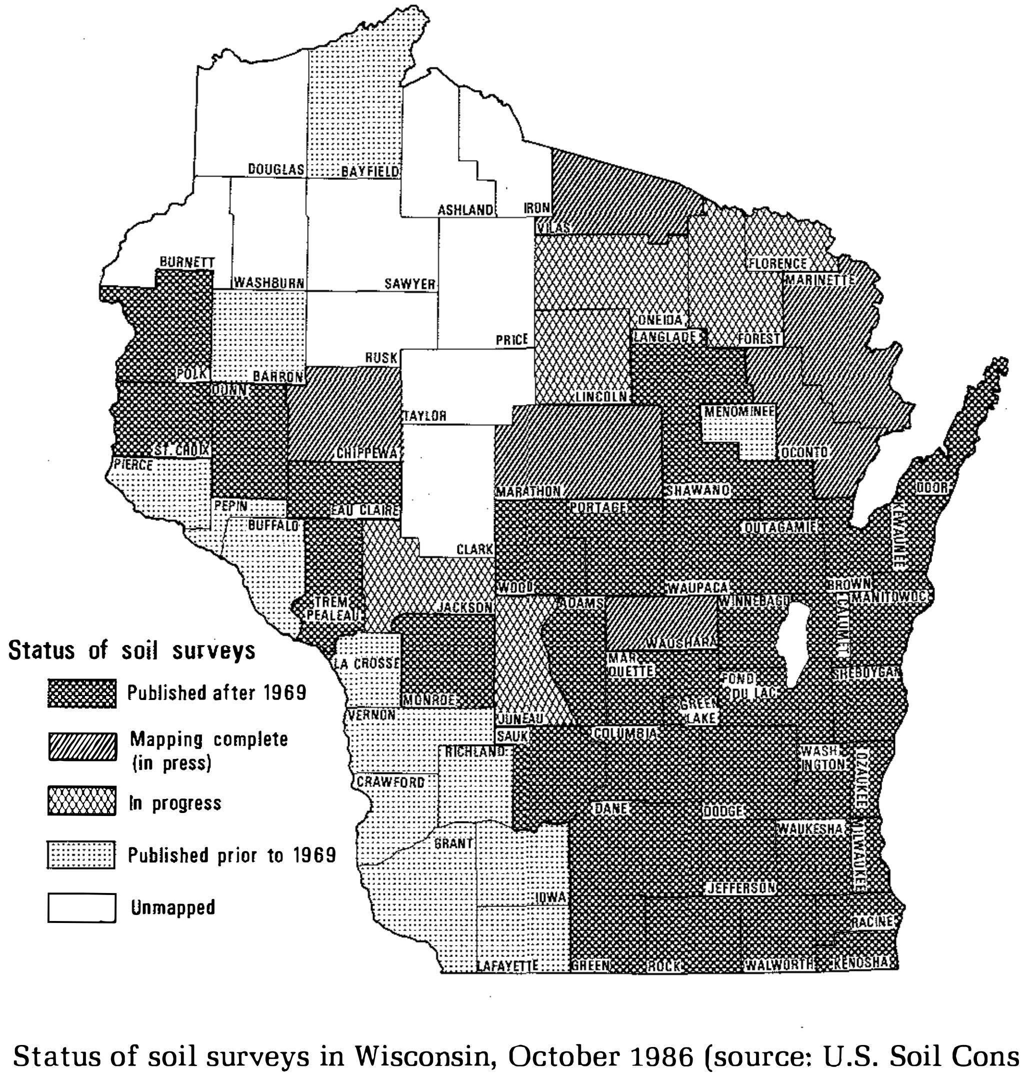


Figure 6. Status of soil surveys in Wisconsin, October 1986 (source: U.S. Soil Conservation Service).

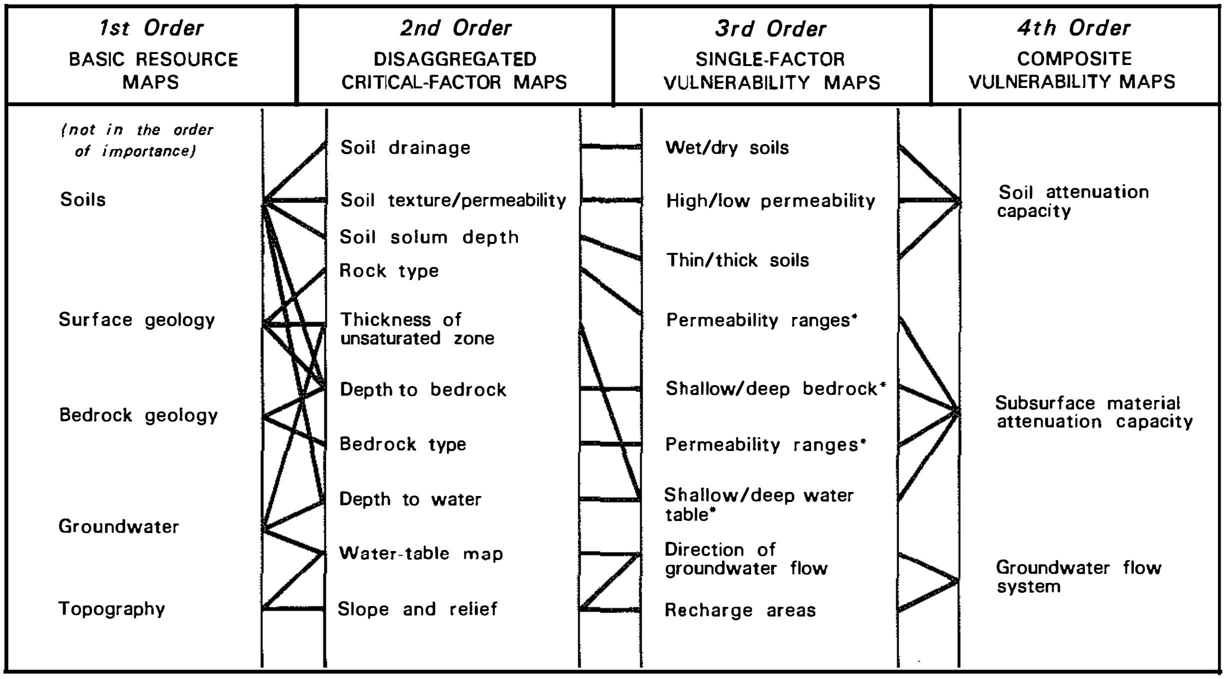
Use of the System

Figure 7 delineates the steps involved in the evaluation system. The first step involves gathering basic resource data from agencies who collect and disseminate them: soils (SCS), surface and bedrock geology and groundwater (WGNHS and USGS), and topography (maps produced by USGS and distributed by WGNHS). The basic resource data must be converted to a common base map and scale so they can be integrated and manipulated for the desired purpose.

In the second step, basic resource maps are used to produce a series of maps that show factors critical for evaluating groundwater vulnerability to pollution. These maps express a property of a particular resource; for example, depth to bedrock is compiled using information from soils, surface geology, and bedrock geology maps. Up to this point, the work required for using the system is comparatively routine and does not require sophisticated technical knowledge.

The next step--compilation of single-factor vulnerability maps--is the subjective portion of the system and requires skilled, professional judgment in selecting threshold permeability ranges and intervals of depth ranges. The system is not based on fixed numerical values; relative vulnerabilities are determined from place to place depending on local conditions and data availability. More details can be found in Zaporozec (1985). Intervals used in that study are presented in figure 8. The single-factor maps can be prepared on transparencies to facilitate compiling the composite vulnerability map.

A composite view of the capacity of soils and subsurface materials to attenuate pollutants can be obtained by stacking all of the single-factor vulnerability maps. Stacking can be done photographically or manually by overlaying individual single-factor



* No numerical guidelines are given in this chart; specific intervals and ranges require professional judgement. Intervals used in the Rock County study (Zaporozec, 1985) are shown in figure 8

Figure 7. Steps in evaluating groundwater vulnerability to pollution.

maps drawn on transparent material (or by computer if an automated natural resource data system is available). The attenuation capacity maps generally show three levels of vulnerability to groundwater pollution:

1) Areas of greatest attenuation potential that are least vulnerable to pollution.
2) Areas with the least attenuation potential that provide little or no protection to groundwater.
3) Areas that contain a variety of conditions between the greatest and least attenuation potential and are moderately vulnerable to pollution.

This system relies on factors that are normally available and used in similar vulnerability systems: depth to bedrock and water and characteristics of soils, unconsolidated deposits, and bedrock. The evaluation system can be simplified further. For example, Sherrill (1979) used three factors for evaluating pollution potential of the dolomite aquifer in eastern Wisconsin: depth to water table, depth to bedrock, and permeability of unconsolidated materials. In a study of groundwater pollution of Winnebago County, Miazga (1985) used only two factors--soil permeability and depth to bedrock--in combination with the direction of groundwater flow.

Permeability and Thickness of Rock Materials (below the first 5 ft)	Thickness of the Unsaturated Zone (ft below surface)		
	>50	10-50	>10
Dolomite within 20 ft from the surface (any overburden)	1	1	1
Thick (over 50 ft) sand and gravel (over any bedrock)	2	1	1
Sandstone within 20 ft from the surface (any overburden)	2	1	1
Dolomite overlain by medium-thick (20-50 ft) sand and gravel	2	1	1
Sandstone overlain by medium-thick (20-50 ft) sand and gravel	2	2	1
Dolomite overlain by medium-thick (20-50 ft) till	3	2	1
Sandstone overlain by medium-thick (20-50 ft) till	3	2	2
Thick (over 50 ft) till (over anything)	3	3	2

Increasing Pollution Potential

Increasing Pollution Potential

Scale: 1 - greatest potential, 2 - moderate potential,
3 - least potential

Figure 8. System for evaluating pollution potential of subsurface materials in Rock County (from Zaporozec, 1985).

Local governments can use composite vulnerability maps to prioritize areas for groundwater protection programs. Whether groundwater will be polluted depends on what types of pollutants and land uses are located in the area and how sensitive that area is to pollution. There are many limitations on the use of composite maps. The maps highlight pollution-sensitive areas, and show them in a generalized way. Because of the map scale, it is impossible to illustrate the properties of every parcel of land; and an area classified as suitable for a particular purpose may contain small tracts of unsuitable land, or vice versa. Therefore, the maps cannot be used for any site-specific purposes. They do, however, reduce the number of areas to be studied in detail by identifying those with the greatest or least limitations.

Chapter VI.

MANAGEMENT TECHNIQUES

Local governments, in cooperation with state and federal agencies, play an important role in groundwater management. Techniques that can be used in local groundwater protection programs can be categorized as regulatory and nonregulatory approaches, although in practice, most programs are a mix of these. Regulatory approaches involve placing a system of legal constraints on land uses or on particular activities that have a potential to pollute the groundwater. Nonregulatory approaches include such activities as public education, voluntary best management practices, governmental coordination, inspection and training programs, emergency spill response plans, and monitoring to identify water-quality problems.

Many potential pollution sources are being regulated by the state. Local government should take these regulations into consideration so that the proposed local actions are not in conflict with them. State regulatory programs that affect groundwater directly or indirectly can be grouped into four categories: waste disposal, agriculture, hazardous materials and waste, and other activities. Table 4 presents a summary of existing state regulations related to groundwater protection. Many new regulations resulted from the enactment of the Wisconsin groundwater protection law, 1983 Wisconsin Act 410, which requires the development and implementation of a two-tiered system of numerical standards for substances that could pollute groundwater (Appendix B).

Local Regulatory Tools

An Overview

Local regulations that control the location of land uses, specify the types of permitted activities, and regulate the density of use can play an important role in groundwater protection. Table 5 summarizes those regulations which relate to groundwater protection.

In addition to considering what to regulate and how to regulate it, it is necessary to determine which unit of government has the authority to adopt a particular regulation. Two basic questions must be answered: 1) Has that unit of local government been empowered to act; and 2) Has the state preempted local authority? Generally, cities and villages have home-rule powers allowing them to regulate unless there is a statute indicating they may not. Towns with village powers may exercise such powers, except those "which conflict with statutes relating to towns and town boards." Towns without village powers and counties, on the other hand, must find a statute authorizing them to regulate. Yanggen and Amrhein (in preparation) discuss local powers and state preemption at length.

In some cases the law gives the state sole authority to adopt certain types of regulations. For example, under the groundwater protection law (1983 Wisconsin Act 410), the state has preempted the right to set groundwater quality standards. On the other hand, this law allows counties to adopt and enforce well codes and ordinances controlling land disposal of septage and, thus, enables them to administer state regulations. Cities, villages, towns, and counties are now also specifically authorized to adopt zoning to protect groundwater. The law also requires the state to regulate bulk storage of fertilizers, pesticides, and road salt, but does not indicate whether these responsibilities can be shared with local government. Generally, the state has preempted regulatory authority where: 1) state statute expressly withdraws local power, 2) the ordinance logically conflicts with state legislation, or 3) the ordinance defeats the purpose or goes against the spirit of state legislation.

Table 4. Summary of state regulatory controls of pollution sources

Activity	Regulator	Code	Focus of regulations
WASTE DISPOSAL			
Municipal and industrial landfills	DNR	NR 180* NR 185*	Licensing of all sites; standards for location, design, operation, construction, monitoring, and abandonment.
Environmental response and repair	DNR	NR 550	DNR maintains an inventory of sites that might pollute and hazard ranking list of the sites; sets procedures for emergency response and repair.
Municipal and industrial wastewater	DNR	NR 110 NR 206* NR 214	DNR regulates through WPDES permit process. NR 110 governs municipal sewage lagoons; NR 206 land disposal of municipal wastewater; and NR 214 land disposal of industrial wastewater.
Sanitary sewers	DILHR	ILHR 82	DILHR regulates laterals.
	DNR	NR 110	DNR regulates interceptors and collectors.
Private wastewater systems	DILHR	ILHR 83 ILHR 85	DILHR regulates siting, design, installation, and inspection of systems and licensing of installers and evaluators. State inspection system (vs. local) is required for large-scale systems.
	DNR	NR 113*	DNR can prohibit tanks in areas where they cause a water quality problem.
Municipal sludge disposal	DNR	NR 110	NR 110 requires approval of land for sludge disposal;
		NR 204	NR 204 regulates land spreading of sludge.
Septage and holding tank waste disposal	DNR	NR 113* NR 206*	DNR licenses persons for holding-tank maintenance and waste disposal and regulates land spreading of domestic wastewater.

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* Currently being updated or revised.

Table 4. Summary of state regulatory controls of pollution sources (continued)

Activity	Regulator	Code	Focus of regulations
AGRICULTURE			
Animal waste management	DATCP	Ag 165	Sets requirements for county animal-waste management plan, including ordinances establishing minimum standards for earthen manure-storage facilities; provides cost-sharing for farmers involved in animal-waste management program.
	DNR	NR 112 NR 243 NR 120	DNR regulations for livestock feeding operations include well location distances, runoff structures, use of WPDES permits, design standards, and storage requirements. NR 120 provides cost-sharing through the Nonpoint Source Pollution Abatement Program.
Fertilizer bulk storage	DATCP	Ag 162	Contains standards for storage containers and appurtenances, loading areas, secondary containment, and abandoned containers; the emphasis is on liquid fertilizer.
Pesticide storage, transportation, and use	DATCP	Ag 29	Rules require good handling practices and prohibit entry of pesticides into the groundwater above an enforcement standard; also has aldicarb restrictions and groundwater sampling requirements.
	DATCP	Ag 163	Standards and requirements parallel those of fertilizer bulk storage.
	DNR	NR 80	DNR can prohibit use of pesticide; Pesticide Review Board review is required.
Regulation of agricultural chemicals	DATCP	Ag 161	Establishes standards for groundwater test reporting and the regulatory and enforcement actions to prevent and control groundwater pollution from agricultural activities.
HAZARDOUS MATERIALS AND WASTE			
Hazardous waste	DNR	NR 181*	Establishes criteria for identifying the characteristics of hazardous waste and management regulations for their treatment, storage, and disposal.
Engine waste oil	DNR	NR 183	Requirements for location, design, and operation of facilities.

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* Currently being updated or revised.

Table 4. Summary of state regulatory controls of pollution sources (continued)

Activity	Regulator	Code	Focus of regulations
PCBs	DNR	NR 157	Establishes procedures for collection, storage, transport, and disposal of PCBs and products containing PCBs.
Chemical storage tanks	DILHR	ILHR 10*	Leak detection program, plan review, tank inspection and approval, design and construction standards, and record-keeping.
Spills	DNR	NR 158	Contingency plan required for emergency response to hazardous substances. DNR has authority to request remedial action.
Abandoned containers	DNR	NR 551	Establishes criteria and procedures for developing contingency plans to respond to abandoned containers of hazardous substances.
OTHER ACTIVITIES			
Well construction and abandonment	DNR	NR 112 NR 111	DNR licenses well drillers and pump installers, specifies well design and construction, sets minimum separating distances between wells and potential pollution sources, and requires proper abandonment of all wells.
		NR 145	DNR can authorize counties to administer NR 112 at one of four delegation levels.
Well compensation	DNR	NR 123	DNR provides partial reimbursement for replacing contaminated wells.
Drinking water standards	DNR	NR 109	DNR sets drinking water standards and public water supply monitoring requirements.
Groundwater standards	DNR	NR 140	Sets up a two-tiered system of numerical standards for polluting substances enforced by DNR, and establishes groundwater quality standards for harmful substances.
Highway salt storage	DOT	TRANS 277	Provides for DOT response when the prevention action limit for chloride has been exceeded at a storage facility and sets requirements for remedial action.

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* Currently being updated or revised.

Table 5. Summary of local regulations related to groundwater protection

Activity	Regulator	Authority Wisconsin Statutes	Adm. Code	Focus of regulations
Land use (zoning)	County City & Village Town	59.97 61.35&62.23(7) 60.61&60.62		Regulation of new land use locations, special areas and activities, and plans of operations for conditional uses.
Land division (subdivision)	County City & Village Town	236.45		New parcel creation.
Septage disposal	County (otherwise) City & Village Town	146.20(5m)	NR 113	Regulation of land spreading of domestic wastewater.
Livestock waste management	County	92.16 59.07(51)	Ag 165	Regulation of earthen collection and storage facilities. Regulation of feeding and holding areas.
Hazardous materials	County City & Village	59.07(51) home rule*		Regulation of storage, handling, disposal, and spillage of hazardous materials (types and amounts not covered by state).
Chemical storage tanks	City & Village Town	101.14(2)	ILHR 10	Regulation of periodic tank inspection, testing, approval, and removal as well as record-keeping.
Well construction and abandonment	County (only)	59.067	NR 112 NR 145	Regulation of well construction and/or pump installation, abandonment of unused wells, and location of new facilities.

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* Municipal home rule powers--Wis. Statutes, sec. 62.11(5) (cities) and sec. 61.34(1) (villages).

The county's broad geographic coverage puts it in a key position to coordinate the groundwater management activities of the state and other local governments. County government should also coordinate its regulatory activities with those of other local governments and the state. Discussion with representatives of state agencies can 1) help clarify the extent to which state regulations have preempted local authority, 2) avoid unnecessary duplication of regulations, 3) be a source of technical information and assistance, and 4) help coordinate administrative details in terms of permits, inspection, and enforcement.

Coordination among the county and the towns and the incorporated municipalities is equally important. Changes in the county zoning ordinance must be approved by the towns affected. Well-protection zoning regulations have to be adopted by cities and villages because the county authority does not extend inside municipal corporate limits. Authority to administer the DILHR code relating to underground petroleum tanks belongs to city, village, and town fire departments, but not to counties. Counties, on the other hand, may regulate the land disposal of septage and may adopt a well code; and both of these regulations would apply within cities, villages, and towns.

The county must be authorized by statute to adopt regulations, unlike cities and villages, which have broad home rule powers. The county has specific groundwater-related regulatory authority in the areas of zoning, construction of earthen animal-waste storage facilities, well codes, and spreading of septage. We have interpreted the authority granted to counties to adopt and administer sanitary codes (sec. 59.07(51), Wis. Statutes) as a source of additional powers. We believe it can be used to protect public health and safety by regulating activities that could pollute groundwater. We also use it as the basis for suggesting that counties could adopt a hazardous materials ordinance and regulate certain aspects of livestock waste management. A more conservative interpretation of the statutes might disagree with our conclusion; counties should consult with their legal advisors for their opinions. An extensive legal analysis of state-local regulatory relationships is found in Yanggen and Amrhein (in preparation).

This section outlines several local regulatory options. The discussion of each regulatory program includes: A) the general elements of the program, B) legal considerations including local regulatory authority, C) advantages and D) limitations of each measure, and E) an evaluation of the applicability of the program. Yanggen and Webendorfer (1984) detail local land use regulatory options for groundwater protection.

Zoning

A. Elements -- Zoning can be used to regulate land use to protect groundwater quality. Several approaches are available that can be used either separately or in combination.

1) A general approach -- review the zoning ordinance to designate activities involving hazardous materials conditional uses and review zoning district boundaries, for example, to make sure that the industrial zoning district is located a safe distance from municipal wells.
2) A naturally vulnerable areas approach -- establish an overlay district where the potential exists for rapid movement of pollutants to groundwater.
3) A well-protection districts approach -- regulate potential pollution sources near municipal wells via an overlay district.
4) A potential problem areas approach -- delineate and regulate areas where potential pollution sources are concentrated in naturally vulnerable areas or where land uses are "down flow" from sources of suspected pollution.

B. Legal authority -- Cities, villages, towns, and counties are authorized to adopt zoning to protect groundwater and can use any or all of the approaches described previously. A zoning conditional use may be regulated in terms of how the activity is carried out, i.e., control over the plan of operations. The state can also regulate how certain activities may be conducted at times, for example, fertilizer and pesticide storage. In some instances the state may have the sole authority to regulate how the activity is carried out. Stringency of regulations must relate to the potential severity of harm so that constitutionally protected property rights are not infringed on.

C. Advantages -- Zoning is preventive and ensures that groundwater protection is considered when development is proposed. Groundwater concerns can be addressed by an existing regulatory framework through permits, enforcement, and administration. Delineating special management areas through the use of overlay zoning districts can match the zoning use restrictions to the susceptibility of the area to the pollution.

D. Limitations -- Uses in existence before passage of zoning or its amendment are permitted to continue as nonconforming uses. Some states permit amortization of nonconforming uses; they require that the uses conform to the ordinance within a specified time or else be removed. Wisconsin courts have never decided whether this may be required. Zoning does not regulate the manner in which permitted uses or nonconforming uses may be carried out. This type of control applies only to conditional uses.

E. Evaluation -- Zoning is an important tool to control new land uses to protect groundwater.

Extraterritorial Zoning

A. Elements -- Same as conventional zoning if it is permanent extraterritorial zoning.

B. Legal Authority -- First, second, and third class cities can zone up to 3 miles outside their city limits; fourth class cities and villages can regulate up to 1.5 miles beyond their boundaries.

C. Advantages -- Extraterritorial zoning allows an incorporated municipality to regulate uses that might pollute its water supply where the municipal well or the area of influence of the well lies beyond municipal boundaries.

D. Limitations -- The municipality can adopt interim extraterritorial zoning for a maximum of 2 years without the consent of the affected town. This interim zoning freezes whatever zoning is already in effect. If the area in question is not already zoned, the interim zoning freezes development to what is there at the time the interim zoning takes effect. For the extraterritorial zoning to remain in effect after the initial 2 years it must be agreed to by an extraterritorial zoning committee with equal representation from both the municipality and the affected town government.

E. Evaluation -- Extraterritorial zoning may enable a municipality to take emergency action through the 2-year interim freeze period to control land uses that may threaten its water supply. The municipality must secure the cooperation of the town board, however, if the zoning is to become permanent. Municipal extraterritorial zoning has not been widely used in Wisconsin.

Subdivision Regulation

A. Elements -- Subdivision regulation controls division of land into lots for sale or development and can require proper stormwater and groundwater management. Traditionally, subdivision regulation has focused on residential development, but it can also apply to commercial and industrial development.

B. Legal authority -- Groundwater protection is clearly authorized. Cities, villages, towns, and counties can adopt regulations, and cities and villages can regulate outside their corporate limits. If municipal extraterritorial, town, and county subdivision regulations apply to the same property, the most stringent provisions take precedence.

C. Advantages -- Municipalities can regulate 3 miles (1st, 2nd, and 3rd class cities) or 1.5 miles (4th class cities and villages) outside their corporate limits. Subdivision regulation can control lot size and, to some extent, the type of land use permitted, particularly if the regulation is used to implement a plan.

D. Limitations -- Subdivision regulation only applies when a new parcel is created. Subdivision regulation is better for controlling how lands are developed than for controlling the type of uses permitted and the way these uses are carried out.

E. Evaluation -- Subdivision regulation is important for supplementing zoning when new parcels are created.

Regulation of Landspreading of Sludge

A. Elements -- The purpose of local controls would be to prevent pollutants in the sludge from reaching the groundwater. Site criteria and application rates would have to be identical to DNR rules (chaps. NR 204 and NR 214, Wis. Administrative Code).

B. Legal Authority -- Although the state probably has the exclusive authority to regulate the manner of landspreading of sludge, DNR has seldom challenged local regulations if they are reasonable.

C. Advantages -- By regulating the landspreading of sludge an important pollution source can be controlled. Local government is in the best position to inspect spreading at individual sites.

D. Limitations -- The legal authority of local government to regulate is vague because of probable state preemption.

E. Evaluation -- Local government could request that DNR prohibit land disposal of sludge in vulnerable areas and in well-protection zones, and could ask for concurrent local authority to inspect spreading operations at sites. Regulation of the location of sludge disposal sites under zoning to ensure compatibility with adjoining land uses remains a local governmental function.

Regulation of Landspreading of Septage

A. Elements -- The groundwater law (sec. 146.20(5m), Wis. Statutes) specifically authorizes county regulation of the land disposal of septage. The site criteria and disposal procedures specified in the septage ordinance must be identical to DNR rules (chaps. NR 113, Wis. Administrative Code). The ordinance must also require a soil test and annual license for each site. The county must maintain records of soil tests, site licenses, inspections, and enforcement actions.

B. Legal authority -- Chapter 146.20(5m), Wis. Statutes, states that a county may apply to the DNR for authority to regulate land disposal of septage. The county must include an ordinance and a description of its administrative capabilities with the application. Section NR 113.11, Wis. Administrative Code, contains the detailed requirements for county regulations.

C. Advantages -- Proper disposal of septage is important to protect ground- water, and local government is in a better position than the state to make on-site inspections.

D. Limitations -- The details of what will be required of local regulatory programs will be established by the fall of 1987.

E. Evaluation -- Adoption of a county-level septage regulation should be investigated when the DNR administrative rules spelling out the revised state and local regulatory roles are promulgated. If the county does not adopt such a code, cities, villages, and towns may do so.

Livestock Waste Ordinance

A. Elements -- Livestock waste ordinances require animal-waste storage facilities and their management to meet technical standards.

B. Legal authority -- County regulation of earthen animal-waste storage facilities is clearly authorized by sec. 92.16, Wis. Statutes. Other types of facilities can probably be adopted as part of a sanitary ordinance under sec. 59.07(51), Wis. Statutes.

C. Advantages -- If a county adopts an ordinance under sec. 92.16 Wis. Statutes, and a county animal-waste management plan under sec. 92.15, Wis. Statutes, farmers are eligible for special cost-sharing programs for barnyard runoff systems and livestock waste storage facilities under the Wisconsin Farmers Fund.

D. Limitations -- It is not clear whether waste management regulations adopted under sec. 59.07(51), Wis. Statutes (county sanitary regulations), must be solely health-related. This is a traditionally unregulated area and regulations may encounter resistance from those affected.

E. Evaluation -- Animal-waste storage ordinances may address only a fraction of the problem, bypassing the larger issue of managing livestock waste from confined feeding and holding areas. The earthen animal-waste storage ordinance must apply countywide, but other animal-waste management regulations could be limited to critical areas.

Hazardous-Substance Ordinance

A. Elements -- A hazardous-substance ordinance identifies hazardous substances and requires initial and periodic reporting by new and existing enterprises that store, handle, and use these substances. It establishes standards for storage and handling and requires contingency plans in case of spills. It also provides for inspection and enforcement.

B. Legal authority -- Current DNR regulations apply to hazardous wastes (chap. NR 181, Wis. Administrative Code) and to hazardous-substance spills (chap. NR 158, Wis. Administrative Code). Anyone generating any amount of hazardous waste (other than households) must comply with certain standards, including sending the waste to an approved facility. Hazardous substances, i.e., materials that are not yet wastes but which are to be used in a production process, are not subject to state standards for reporting, inspection, storage, or handling. Examples of these types of hazardous substances are certain solvents, degreasers, thinners, caustics, laboratory chemicals, and cleaning fluids.

C. Advantages -- The ordinance can be applied to existing as well as new uses unlike zoning, which applies primarily to new uses. It provides detailed control over storage and handling activities and fills in important gaps in state regulations.

D. Limitations -- Self-reporting by existing facilities may be ineffective. Counties would have to control hazardous substances under their authority to adopt sanitary regulations, but municipalities could use statutory home-rule powers. Identifying the substances to be regulated and setting storage and handling standards requires technical expertise, which can be costly. Inspection can also be time-consuming and expensive. This would be difficult to accomplish at the local level. The community right-to-know requirements of Title III of the federal Superfund Amendments and Reauthorization Act of 1986, requires reporting that will help to increase local government's knowledge of and access to information on the presence of hazardous chemicals in their communities. Local action would be facilitated if the state were to prepare guidelines for storage and handling of presently unregulated hazardous substances.

E. Evaluation -- Local governments should consider such an ordinance if state regulations are deemed inadequate. The ordinance could be designed to apply throughout the local unit or to apply only to areas adjacent to municipal wells or to other vulnerable areas. Inspection could be limited to spot-checking the most hazardous sources.

Underground-Storage Tank Ordinance

A. Elements -- An underground-storage tank ordinance would supplement DILHR regulations for underground petroleum storage tanks (chap. ILHR 10, Wis. Administrative Code). One approach would be for local government to supplement state regulations by setting more stringent standards for frequency of inspection, e.g., require tanks 10 or more years old to be tested annually if they are located in well-protection districts or naturally vulnerable areas. An ordinance could regulate underground tanks for non-petroleum products as well.

B. Legal authority -- The above-mentioned DILHR regulations recognize city, village, and town fire chiefs as authorized deputies and make these officials responsible for inspecting, testing, and approving underground tanks of less than 1,000 gallons. The power of local government to set additional requirements in applicable building codes, local zoning, and similar ordinances is also recognized by DILHR. The DILHR regulations will probably become effective late in 1987.

C. Advantages -- Local records could be used to supplement a DILHR inventory of abandoned underground tanks, and local inspectors could make on-site inspections.

D. Limitations -- Inspection may be time-consuming, expensive, and will require technical expertise. Cities, villages, and towns can adopt additional requirements if they do not conflict with DILHR technical standards, but the county authority to regulate existing underground storage tanks is unclear. The potential source of authority is sec. 59.07(51), Wis. Statutes (sanitary regulations).

E. Evaluation -- Local deputies may need special training to inspect tanks. Close coordination with DILHR will be necessary to ensure that all underground tanks presently in use receive periodic testing and that abandoned tanks are located, inspected, and removed. Highest priority could be given to tanks in well-protection districts and other special management areas.

County Well Code

A. Elements -- A county well-code ordinance may require a permit before constructing, reconstructing, or rehabilitating a private well or installing a pump.

B. Legal authority -- Section 59.067, Wis. Statutes, allows DNR to authorize counties to adopt and enforce a well construction or pump installation ordinance or both. Well codes must strictly conform to DNR rules (chap. NR 112, Wis. Administrative Code), and the DNR may revoke county authority if the code is improperly enforced or not in compliance with the administrative rules. Cities, villages, and towns cannot adopt well codes. Chapter NR 145, Wis. Administrative Code authorizes four levels of county involvement: 1) well location and well abandonment, 2) well location and pump installation, 3) existing private and noncommunity water systems, and 4) well construction and responsibilities of levels 1 to 3. For the first 18 months of the program, county operations will be limited to level 1.

C. Advantages -- Inspection of the location of wells can be integrated into the inspections required to determine compliance with other county ordinances such as zoning and septic tank codes. The ordinance should also cover abandonment of unused wells (a potential conduit for pollution). Municipal well abandonment ordinances required under secs. NR 111.26(4) and NR 111.27(1)(c) protect aquifers in municipal areas but apply only to municipalities with public water systems.

D. Limitations -- Inspection, in most cases, would require additional county staff and special staff training. DNR will be conducting training sessions in 1987. The ordinance must apply countywide.

E. Evaluation -- Chapter NR 145, Wis. Administrative Code, spells out standards for county adoption and enforcement of a well construction and pump installation ordinance. After attending training sessions on the new code and discussing it with DNR, a county will be better able to estimate the workload and expenditures required to enforce a county well code.

Local Nonregulatory Programs

This section describes a set of actions usually thought of as voluntary. It should be noted, however, that many of these programs commonly supplement regulatory programs; for example, information programs developed in support of regulating underground storage tanks. This section emphasizes the deployment of these programs in voluntary groundwater protection efforts.

Education and Information

Educational programming should be a component of any effort to protect groundwater. A strong educational program will help citizens and land managers better understand the relationship of land use activities to groundwater quality. Knowledge of the groundwater basics, the sources and nature of pollution threats, and optional management measures is essential if local units of government and citizens are to support and participate in an effort to protect groundwater. Programs can range from those explaining general principles of groundwater protection to specific topics such as toxic-materials handling for small businesses. Programs can take many forms--from traditional films, slide shows, and handbooks to intensive workshops featuring interactive computer graphics. Public media (newspaper, radio, and TV) can also be an effective means of reaching the public. Educational materials and programs can be targeted for specific audiences with defined concerns about groundwater and related management activities. For example, the elementary and secondary population is an especially important audience.

A substantial amount of educational material has been developed in recent years and used throughout the state. A list of materials is available from UW-Extension ("How to Develop Extension Education on Groundwater"). Other information is available from DNR and a combination of these materials could readily serve as part of a "groundwater education kit."

A multifaceted educational program could include:

1) Basic information on the groundwater resource -- Individuals making management decisions must have a basic understanding of how groundwater moves, how land use activities can influence groundwater quality, what happens once groundwater is polluted, and how difficult it is to clean up polluted groundwater.
2) Drinking-water quality education -- Citizens are concerned about water quality because they recognize the need for a safe drinking-water supply. When citizens recognize that land use activities can affect the quality of their drinking water, they will be more inclined to protect groundwater. By improving public understanding that well water should be tested annually and by helping people understand how to interpret test results, educational programs will help individual citizens become more aware of the importance of their role in groundwater quality management.
3) Specialized educational programs -- Specific educational programs should be directed at activities that pose a significant risk to groundwater, such as solid waste disposal, septic system operation and maintenance, and storage of petroleum products or other potentially toxic substances. Examples of such programs would be voluntary courses through local schools for storers, handlers, and haulers of hazardous waste. Coursework could be aimed at concerns such as safety and spill prevention. Educational programs for individual farmers could include topics such as integrated pest management and fertility management.

Waste Reduction

Many communities are evaluating methods to reduce the volume of solid waste put in landfills each year. Waste-reduction measures mean lower costs, energy savings, and reduced environmental problems associated with solid waste management.

Recycling -- Readily recyclable materials (newspaper, corrugated cardboard, glass, aluminum, and ferrous metals) constitute about 55 percent by weight of municipal solid waste. Recycling saves energy; it saves resources by reducing the need to use raw materials; it protects the environment by reducing pollution (of air, water, and land); and it saves and makes money. Recycling requires mandatory or voluntary participation by local residents. Local government can play a major role in setting up recycling centers and can act as a source of information for citizens and businesses interested in participating in a recycling program. Because recycling generally does not deal with hazardous waste, special programs for these wastes may be necessary.

Household Hazardous-Waste Collection/Disposal Programs -- Household hazardous waste is typically disposed of with the rest of the household trash. This practice creates risks in waste collection and disposal, especially with respect to groundwater pollution from municipal landfills. Community pilot programs aimed at safe collection and disposal of household hazardous waste are becoming increasingly popular as a means of dealing with this problem. The DNR can provide assistance with the development of such programs through district or area offices. Most of the successful programs (such as Operation Clean Sweep) involve hiring a waste-service contractor to handle actual collection and disposal of the waste. The costs of these programs, however, have been high in relation to the number of people served and the amount of materials collected. Some issues to be addressed in starting a community household hazardous-waste collection program include identifying the quantities and character of the waste, determining proper management (in terms of efficiency and safety) of the program, and considering relevant economic and legal issues. The municipality incurs legal responsibility in properly disposing of the collected hazardous waste.

Sanitary Districts

Domestic on-site waste disposal systems can threaten some areas with bacterial and viral pollution of groundwater. Even properly operated systems can create nitrate pollution. Failing systems may be caused by improper construction, installation in unsuitable soils, or poor maintenance. These areas can be identified and the formation of sanitary districts encouraged. Town sanitary districts are special-purpose units of government designed to provide sewage treatment, stormwater drainage, water systems, and/or refuse disposal facilities and services. Wisconsin Statutes provide several different procedures for the creation of town sanitary districts. They may be created through a petition process and town board action or by order of the DNR. District powers are derived primarily from secs. 60.30 through 60.316, Wis. Statutes. Sanitary districts can plan, construct, and maintain sewage treatment facilities. In some cases this may consist of limited operations such as periodic septic tank maintenance or pumping holding tanks. They may sell services to users outside their boundaries and contract with other municipalities for services. In addition, districts may issue regulations, such as requiring the installation of private sewage systems, to promote and preserve public sanitation. Town sanitary districts are granted powers to raise revenues to finance their expenditures directly from district residents via property taxes and special assessments or by user or service charges. Sanitary districts can also finance debt and receive federal or state grants and loans.

Agricultural Best Management Practices

Agricultural practices have a long tradition of being changed only by voluntary actions of farmers managing their own land. The exception to this is the handling of hazardous materials, which is regulated at the state and federal level. The following agricultural best management practices (BMPs) will help improve crop-livestock production and management and minimize the potential for groundwater pollution. Technical assistance for farmers wishing to apply them is available from the UW-Extension as well as from state and federal agencies. Jackson and others (in preparation) summarize the most current information regarding agricultural management practices to minimize groundwater pollution.

Livestock Waste Management -- The following principal factors in livestock waste management should be considered when devising a plan for groundwater protection:

1) The proper design, siting, and management of waste storage facilities, especially in areas with thin soils and limiting hydrogeologic conditions.
2) Application of livestock waste to cropland at rates that do not exceed the nitrogen requirements of the crops to be grown.
3) Management of barnyards or livestock holding areas to minimize the potential for groundwater pollution.

Fertility Management -- As a best management practice, fertility management normally results in the efficient use of fertilizer. This is particularly important for nitrogen, a major crop nutrient that may pollute groundwater. An efficient fertilizer program should consider several factors important in reducing excessive fertilizer application and the potential for groundwater pollution. First, such programs should be based on soil test results. Soil tests indicate the site and crop-specific nutrient needs. Fertilizer should be added only at rates needed to meet the crop's needs. Second, the timing of fertilizer application is important. Nitrogen fertilizer should not be applied in the fall. Leaching potential can be further reduced by splitting the application, applying some nitrogen at planting and additional amounts at the time of greatest crop uptake. Placing fertilizers close to crop rows usually increases the efficiency of crop uptake, thus reducing leaching potential.

Pest Control -- Effective pest control is essential for profitable crop production. The integrated pest management (IPM) program is the most effective approach available to minimize the use of chemical pest controls. IPM utilizes pest, crop, and weather data in making pest control recommendations. It promotes the use of non-chemical control methods such as pest-resistant varieties, crop rotation, tillage practices, and adjusted planting harvesting dates. The use of IPM recommendations ensures that pesticides are used only when clearly needed to prevent economic losses. Using this system, pesticides are not only applied at the most effective time, but also at the proper rates and only to targeted areas. IPM stresses proper calibration and operation of application equipment and adherence to all safety precautions. To make this program more usable for growers, crop and pest-specific educational materials are needed on IPM scouting procedures, economic thresholds, and treatment alternatives.

Crop Rotation -- Crop rotation programs are effective in suppressing pests that have a short survival period. Reduced pest activities can reduce pesticide use, thereby reducing the potential for groundwater pollution. It should be noted, however, that not all crop rotation programs that produce the desired groundwater protection benefits are economically feasible for growers. Further research is needed to determine which rotations have the greatest potential to protect the environment without significantly reducing grower's net returns.

Tillage Practices -- In some situations, tillage practices can influence groundwater quality. For example, conservation tillage practices are being used to control wind and water erosion. In some situations, this has increased several insect and disease problems, which may result in the use of more chemicals. Substituting conventional tillage for conservation tillage practices in order to protect groundwater may be advisable in these cases. The use of ridge-tillage systems may have the greatest potential for reducing groundwater pollution while still controlling runoff and erosion.

Pesticide Container and Rinse-Water Disposal -- The improper disposal of pesticide containers and rinse water from application equipment can pollute groundwater. Currently, triple-rinsed pesticide containers can legally be disposed of at DNR-approved landfill sites. It is generally recommended that sprayer rinse water be sprayed back on agricultural fields. This is not always easily accomplished. The development of approved on-farm rinse-water disposal systems would help ensure that rinse water and pesticides are disposed of properly.

Proper Irrigation Scheduling -- In general, more intensive agricultural management is practiced under irrigated conditions. Proper irrigation scheduling is an effective way to ensure that crop water requirements are met and that overapplication of irrigation water does not result in leaching of nutrients or pesticides to groundwater. This is accomplished by balancing the amount of water applied through irrigation with the amount of water supplied through rainfall to meet the water requirements of a particular crop.

Local governments will likely play only a supplemental role in monitoring. They may be able to require monitoring as a condition of granting a local regulatory permit for a land use that may cause groundwater quality problems. The counties may ask the UW-Extension to conduct one of the drinking-water quality testing programs in their counties or may participate in water quality appraisal activities of various state and federal agencies. Local governments may also encourage private well owners to have their wells tested regularly for bacteria and nitrate.

Local governments, with appropriate technical staff and laboratory facilities, can undertake monitoring activities on their own. An example would be a county program for testing for bacteria or nitrate, which is relatively inexpensive. In contrast, testing for other pollutants can be very expensive and can require specialized facilities. Some counties and municipalities, through health or other related departments, may initiate a groundwater sampling program independently or as a supplement to state programs. Any such program must use standardized sample-collection procedures and certified laboratory analyses if the information is to be useful. There is an additional local role--that of making local laboratory facilities available to citizens wanting their wells tested. A local plan should evaluate the available facilities and determine whether the laboratories should be expanded to provide such service.

Local Government's Coordination and Proprietary Role

Coordinating local governmental planning functions represents another management opportunity. For some management options, it may be necessary to seek the cooperation of other local governments in the management effort. Many local units of government and regional agencies are presently engaged in planning activities that will influence existing and future land uses. Soil erosion control plans, areawide water quality management plans, priority watershed plans, solid waste management plans, forest land plans, animal waste management plans, and others have the potential to significantly affect groundwater by encouraging some land uses and management practices while discouraging others.

There is an opportunity to link planning efforts with groundwater protection activities. Every effort should be made to ensure compatibility and consistency of groundwater planning with broader water-quality planning, natural resources planning, and comprehensive planning. Coordinating or integrating various single-purpose plans to accomplish several objectives simultaneously represents a challenge and a chance for real accomplishment at the local level. Designated water-quality planning agencies and comprehensive regional planning agencies can be useful mechanisms for coordinating local planning.

When local government undertakes a groundwater management program that significantly affects its citizens it should set a good example with its own operations. Local government should address its proprietary role in operations such as landfills, waste reduction, storage and handling of hazardous waste, salt storage, road deicing, facilities management, and personnel training for spills and emergencies before it can hope to influence the actions of others.

Chapter VII.

INTEGRATED MANAGEMENT OPTIONS

This chapter begins with a discussion of groundwater protection focusing on "special management areas." We then outline specific strategies and actions that local governments can pursue to protect groundwater from potential pollution sources. The discussion of each source or activity includes: A) relevant state authorities and actions, B) local regulatory options, and C) nonregulatory strategies. The discussion of the local options is based on the analysis of specific local regulatory and nonregulatory techniques presented in the prior chapter.

Special Management Areas

Groundwater quality protection can be pursued by addressing a particular source(s) of pollution or by focusing on specific areas where all potential sources of groundwater pollution are of concern. Such areas--here termed special management areas--can be delineated and officially designated for groundwater protection planning and management activities. As noted earlier, certain areas are naturally more susceptible to pollution than others. In some areas, the mix of land uses and associated activities may pose groundwater pollution problems, and indeed may already have resulted in documented groundwater quality problems. Other areas are particularly important for special management attention because of the use made of the underlying groundwater resource, for example, drinking-water supplies. Special management areas are divided into three categories:

1) Naturally vulnerable areas -- those locations particularly susceptible to groundwater pollution because the soils, subsoils, and bedrock do not provide adequate protection against the rapid movement of pollutants to groundwater.

2) Potential problem areas -- places where potentially polluting uses are concentrated in naturally vulnerable areas or areas where pollutants have entered groundwater.

3) Well-protection areas -- the area contributing groundwater to an existing or planned well.

The delineation and use of special management areas allows local and state governments to target their management efforts into especially critical areas. Using this approach does not mean that the introduction of pollutants in other areas should not be of concern. Rather, it permits screening and priority-setting for those areas most in need of protection.

Naturally Vulnerable Areas

The environmental assessment methods described in chapter V allow areas that are susceptible to the rapid movement of pollutants to be identified. These areas have a very limited potential for attenuating pollutants and require special attention because certain land uses, eventual accidents, or mishandling of hazardous materials may create serious pollution problems there. Other vulnerable areas of concern are the recharge areas of deeper aquifers. If a pollutant is introduced in these critical recharge areas, resulting pollution may eventually spread through the entire aquifer.

Potential Problem Areas

Potential problem areas involve two general situations: 1) areas where uses that could cause pollution (particularly storage and handling of hazardous materials) are concentrated in areas most vulnerable to pollution and 2) areas where suspected pollutants may already have entered the groundwater.

Overlaying the most vulnerable categories from the soil and subsurface pollution potential maps with inventory maps showing the location of individual potential pollution sources or polluting land use activities produces the map of potential problem areas. In addition, incidences of known groundwater pollution should be shown on the map. Such a map is not intended to suggest that these are the only areas in which groundwater quality problems have occurred or might occur. All inventoried pollution sources have a potential to create groundwater quality problems. The map merely shows the potential and known problem areas of highest priority at the time of the study. Hence, this map should be used only as a planning tool to help develop different strategies for dealing with known and potential problems. Areas of known pollution will not necessarily coincide with the areas most sensitive to pollution. Ultimately the map can be used as a guide to areas that should be addressed first in a groundwater protection plan. Further, each of the potential pollution sources located in pollution sensitive areas has a different risk depending upon the potential pollutants and the design, construction, and maintenance of facilities. Therefore, additional monitoring and/or investigation will be necessary to determine what degree of risk to groundwater, if any, the individual sources present.

The purpose of identifying and regulating the areas of known or suspected pollution is to restrict development "down flow" from such sources unless the developer can ensure an adequate supply of safe water. Information needs can vary substantially, depending upon the nature of the problem. If development is proposed in the vicinity of a suspected pollution source such as an abandoned dump, the basic information needed is the direction of the groundwater flow, the shape of a pollution plume, and the nature of the pollutants. With this information, government can establish special regulatory limits down flow of the site where particular attention is paid to groundwater quality. For example, in the case of a residential development, subdivision regulations can require the developer to monitor water quality and post a long-term performance bond along with an agreement to provide a safe private water supply.

Well-Protection Areas

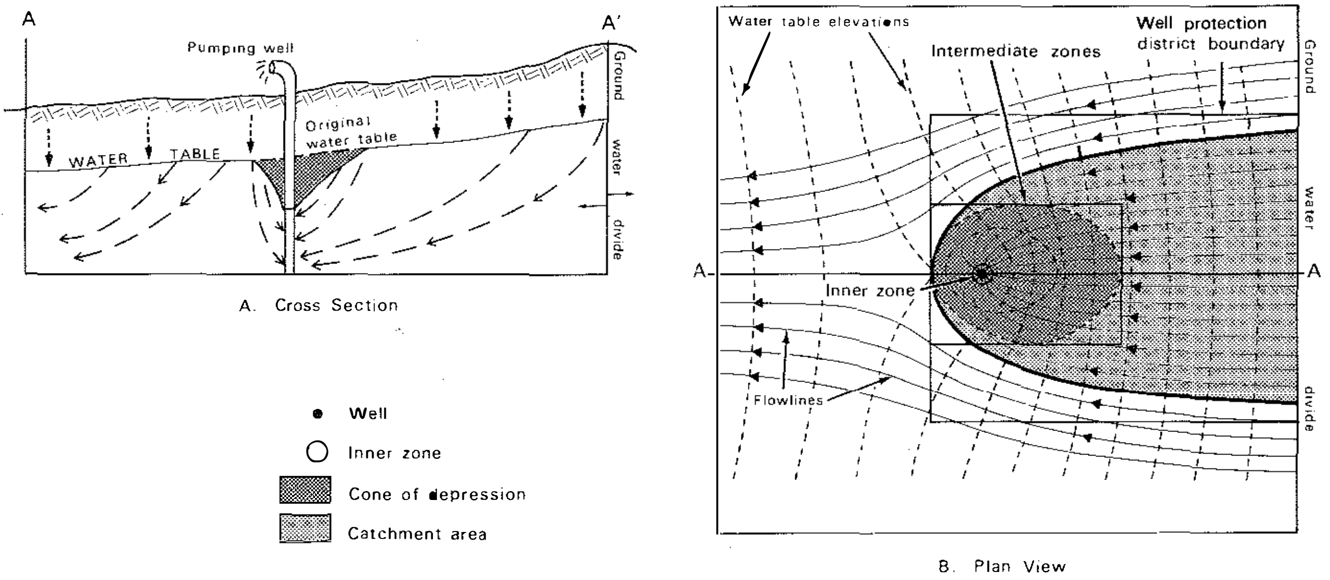
Drinking-water supplies may be protected by delineating well-protection management districts, in which potentially polluting uses and practices are controlled. This areal approach is most appropriate for protecting wells in unconfined (water-table) and semi-confined aquifers. This well-protection district approach is less applicable for wells that obtain water from deeper confined aquifers. Well-protection areas are determined by hydrogeologic analysis and identify the land areas contributing groundwater to a well or wellfield. Well protection areas may be subdivided into several subareas. These areas can serve as the basis for the delineation of appropriate management zones within the overall well protection district (fig. 9). In most cases management district boundaries will need to relate to political and administrative boundaries, and physical factors, as well as hydrogeologic factors. A well-protection district may cover anything from the immediate area around a well to the entire catchment contributing groundwater to a well.

The smallest management zone, the inner zone of protection, is the immediate area around the well with a minimum radius of 50 feet. In Wisconsin, the inner zone boundary is defined by the requirements of chap. NR 111, Wis. Administrative Code, which states that for wells serving municipalities and subdivisions "a lot or parcel of land shall be reserved for the construction of the well, which has minimum dimensions of 100 feet by 100 feet." This zone should be protected against all human activities.

The well protection district ideally should include the entire catchment contributing groundwater to a well. This catchment area is the upgradient part of the aquifer recharge area inside which flowlines move toward the well; outside the catchment area, flowlines are unaffected by pumping the well. Of course, increased pumping in the future or new wells could increase the recharge area of the aquifer contributing to the wells; this should be taken into account in local aquifer protection policies.

In some cases, the catchment area and resultant management district may be too large to allow effective management. One way to reduce its size to manageable proportions is to select a smaller portion of the catchment area as an intermediate zone of protection. This zone can include, for example, the "cone of depression" around the well, which includes that portion of the catchment area in which groundwater elevations are lowered by pumping. Any water-table well, when pumped, creates a cone of depression, that is, the original water table in the vicinity of a pumped well drops. The surface projection of the cone of depression is roughly circular or oval depending on the slope of the water table. The size and shape of each cone varies depending upon the pumping rate, duration of pumping, slope of the water table, and recharge within the zone of influence of the well. Pollutants entering the ground above the cone of depression can move rapidly to the well and thus pose the greatest threat. Therefore, this area should always be protected against undesirable uses.

Other limits of the intermediate protection zone extending beyond the cone of depression can be expressed in terms of time or distance. This is based on the concept that pollution tends to be attenuated more the longer the time and the farther the distance travelled. The time/distance considerations used for justifying and delineating protection zones should be based not only on the concept of pollutant attenuation, but also on the need for and timing of emergency or remedial measures should pollutants be detected moving toward the well(s).



A. Cross Section

B. Plan View

Figure 9. Well-protection district and management zones (adapted from Zaporozec, 1985).

There are numerous methods for delineating a well protection zone. These range from relatively simple approaches that circumscribe a circle of some fixed radius around the well(s) to technically complex methods involving computer models and hydrogeologic mapping and aquifer testing aimed at more accurate delineations. Different methods have differing costs, data and analytical capability requirements, and other factors associated with them. The most sophisticated techniques for delineating protection zones are not necessarily the best; each approach has its own strengths and limitations. A detailed description and analysis of wellhead protection district delineation methods, including case examples from Wisconsin, is presented in Born and others (in preparation).

Under the 1986 Amendments to the federal Safe Drinking Water Act, states need to develop programs to protect wellhead areas and to submit within three years their programs to the U.S. Environmental Protection Agency for approval. Currently, Wisconsin DNR is developing a state program to respond to this new law. Further information regarding the specific requirements for this federal program is available from EPA, and will be available from DNR as the state program develops.

Management of Potential Pollution Sources

Solid Waste Disposal Sites and Junkyards

A. State authorities -- The DNR, through chaps. NR 180 and 185, Wis. Administrative Code, regulates the siting, construction, operation, monitoring, and closure of landfills. These provisions are currently being revised and will appear in chaps. NR 500 through 520, Wis. Administrative Code. DNR can impose conditions deemed necessary to protect groundwater on the operation and abandonment of the landfill. As of October 1985, 2,682 abandoned waste sites were identified and reviewed; 12 percent as high priority for follow up, 61 percent as low priority, and 27 percent unknown due to a lack of information (Bakken and Giesfeldt, 1985). New sites must be monitored, and monitoring of public and private wells in the area may also be required. The DNR is currently inventorying abandoned landfills and will be determining their potential impact on the environment (Bakken and Giesfeldt, 1985). The environmental repair law of 1983 (sec. 144.442, Wis. Statutes) resulted in the creation of chap. NR 550, Wis. Administrative Code, which regulates inventorying, ranking, and repair of site or facilities threatening environmental pollution. The rules focus on an environmental response plan to accomplish the following: outline methods for compiling and maintaining an inventory of all sites and facilities in the state that have the potential to pollute the environment; develop a hazard-ranking system for these sites and facilities; establish methods and criteria for determining remedial actions to be taken; establish a process for balancing remedial-action costs with the associated benefits; and specify the roles and responsibilities of federal, state, and local units of government.

In the past, junkyards have been regulated as solid waste facilities. Because there was a lack of documented pollution problems from these activities, DNR authority to regulate junkyards was removed. DNR can investigate sites and respond to emergency cases that imminently threaten health and the environment.

B. Local regulatory options -- Chapter 144, Wisconsin Statutes, restricts local authority to regulate the siting of a solid waste disposal site. Only local regulations in effect for at least 15 months are recognized and these may be invalidated in an arbitration award granted by the state Waste Facility Siting Board. Local government can amend its zoning and subdivision ordinances to require developers to install monitoring wells in areas of known abandoned waste sites. The developer must prove that groundwater in the area is not polluted. Local governments can regulate automobile salvage yards under the hazardous materials ordinance or under a separate ordinance authorized by sec. 175.25 (cities, villages, and towns) or sec. 59.07(38)(counties), Wis. Statutes. Programs can also be established by local government to ensure that hazardous materials remaining at the sites are properly handled and to prevent illegal dumping at the sites.

C. Nonregulatory options -- Intergovernmental cooperation is essential to deal with pollution problems originating at abandoned sites. Efforts should be made to open channels of communication between state and local governments regarding management strategies, monitoring, remedial actions, and information sharing. For example, local government can ask to become actively involved in the ongoing state inventory of abandoned solid waste sites and in the risk assessment process. The need to monitor high-risk sites can be identified at the local level.

Municipal Wastewater Disposal

A. State authorities -- Chapter 147, Wis. Statutes, requires any person discharging pollutants into the waters of the state to obtain a Wisconsin Pollution Discharge Elimination System (WPDES) permit from DNR. Chapter NR 110, Wis. Administrative Code, governs the design standards and site selection requirements for sewage treatment lagoons. Chapter NR 206, Wis. Administrative Code, regulates land disposal of municipal wastewater, including effluent limitations and monitoring requirements for discharges of liquid waste to land disposal systems, such as seepage pond systems, ridge and furrow systems, spray irrigation systems, and surface spreading systems. The current rules governing municipal sewage lagoons (chaps. NR 110 and 206, Wis. Administrative Code) are being revised to reflect stipulations in the new groundwater law. Chapter NR 214, Wis. Administrative Code, contains regulations for the land application and disposal of liquid industrial waste and by-products. State regulations also control sanitary sewers. DILHR, through chap. ILHR 82, Wis. Administrative Code, regulates all lateral connections, requiring them to be "water tight." DNR, through chap. NR 110, Wis. Administrative Code, regulates all interceptor and collector sewers and establishes leakage criteria and well-separation distances from sewers.

B. Local regulatory options -- Municipalities can regulate materials that may be discharged to sanitary sewers. In addition, sec. 144.08, Wis. Statutes, authorizes municipal sewage systems that are required to accept septage to adopt appropriate regulations. DNR has prepared a model ordinance.

C. Nonregulatory options -- Proper operation and maintenance of sewage treatment plants and sanitary sewers is a local responsibility. A county can inventory and characterize surface wastewater impoundments and seepage cells and recommend sites for monitoring to the state.

Private Wastewater Systems

A. State authorities -- Siting, design, installation, and inspection of all private wastewater systems and licensing of site evaluators, installers, and inspectors fall under the regulatory framework of DILHR (chaps. ILHR 83 and 85, Wis. Administrative Code). Specific authorizing statutes include chaps. 145 and 236, Wis. Statutes. DILHR or DNR can prohibit the installation and use of septic tanks and holding tanks in any area where their use would impair water quality (sec. 144.025(2)(q), Wis. Statutes). In those areas, DNR must prescribe alternative methods of waste disposal. For large-scale systems (cluster or small community) over 8,000 gal/day additional procedures must be followed. State regulations also provide for licensing soil testers and system installers.

B. Local regulatory options -- County government works with DILHR to issue permits and inspect systems. The county has the authority under its private sewage system ordinance to inspect existing systems for soil suitability before issuing any building permit and to otherwise enforce the standards of chap. ILHR 83, Wis. Administrative Code. It can also adopt optional ordinance provisions requiring mandatory maintenance of new and repaired systems and restricting or prohibiting the installation of holding tanks.

C. Nonregulatory options -- Local government can educate the users of septic systems on proper septic tank maintenance and on the dangers of dumping hazardous materials in their septic systems. It can recommend that owners of septic tanks who have private water-supply wells have their water tested for nitrate, especially if the households include pregnant women or infants under 6 months of age.

Land Disposal of Sludge and Septage

A. State authorities -- Sludge handling and approval of land for sludge disposal is regulated by chap. NR 110, Wis. Administrative Code. The DNR regulates landspreading of municipal and industrial sludge through chaps. NR 204 and 214, Wis. Administrative Code, which require a permit, establish site criteria, specify minimum distances from wells, and set application rates. The DNR has the authority to prohibit landspreading of sludge at sites where groundwater quality may be adversely effected. The DNR is responsible for licensing persons for holding-tank maintenance and waste disposal (chap. NR 113, Wis. Administrative Code), while DILHR regulations (chap. ILHR 83, Wis. Administrative Code) address the siting and integrity of septic and holding tanks. This program is in the process of being overhauled. The new groundwater law requires municipal treatment plants, under certain circumstances, to accept septage from licensed septage disposers in an effort to minimize septage disposal on frozen lands. New rules in chap. NR 206, Wis. Administrative Code, prohibit the landspreading of holding-tank wastes if the tank is within 20 miles of a sewage treatment plant that can accept the wastes. The law modifies the state septage disposal regulations and gives counties the authority to regulate septage disposal concurrently with state regulations.

B. Local regulatory options -- Local government can ask the DNR to prohibit sludge spreading in special management areas under the DNR authority discussed above. Counties should review the chap. NR 113, Wis. Administrative Code, standards for the optional county septage program and then decide whether to administer this program.

C. Nonregulatory options -- Counties can develop educational and training programs for septic and holding-tank owners and septage haulers that emphasize the importance of proper septage and holding-tank waste pumping and disposal. Through intergovernment cooperation, a combination of municipal treatment plants that agree to accept septage together with county-designated landspreading sites can be designated and implemented. This will ensure septage disposal that is environmentally safe and economically efficient.

Livestock Waste Storage, Use, and Management

A. State authorities -- For large animal feedlots (more than 1,000 animal units) and smaller operations where pollution problems have been documented, the DNR has regulatory authority through chap. NR 243, Wis. Administrative Code. These rules allow the DNR to mandate specific livestock waste management procedures and to require operators to obtain a WPDES permit. Chapter NR 112, Wis. Administrative Code, regulates the placement of wells in relation to feeding operations. The Wisconsin Farmers Fund, administered by DATCP (chap. Ag 165, Wis. Administrative Code), makes farmers in counties that develop animal-waste management plans and ordinances regulating earthen manure-storage facilities eligible for cost-sharing for installation of manure-storage facilities. There are no state regulations governing landspreading of livestock waste.

B. Local regulatory options -- The county has the authority to develop an ordinance that requires all earthen animal-waste storage facilities to meet minimum design and siting criteria under sec. 92.16, Wis. Statutes. Similar requirements for other types of facilities can probably be adopted under the authority of sec. 59.07(51), Wis. Statutes. The ordinance could also specify standards for land application of livestock waste. Zoning can define new animal feedlots and animal-waste storage facilities as conditional uses where appropriate.

C. Nonregulatory options -- County extension staff and county land conservation personnel can continue to provide livestock producers with information on procedures designed to maximize crop utilization of nutrients available from livestock waste. In developing a countywide livestock waste management plan, the county can undertake an inventory of all existing livestock waste operations and storage facilities. The county can consider requiring the operators to monitor all feedlots located in special management areas.

Fertilizer Storage, Handling, and Use

A. State authorities -- Currently no state regulations govern the land application of fertilizer. A new rule for handling and bulk storage of fertilizers (chap. Ag 162, Wis. Administrative Code) applies to bulk storage of fertilizer by manufacturers and distributors, but not to on-farm storage. The major emphasis is on liquid fertilizer because of the greater risk involved, but the rule also contains general provisions for dry fertilizer. The rule contains standards for storage containers and appurtenances, loading areas, and secondary contaimnent (diking), along with requirements for record-keeping, inspection, maintenance, and development of a response plan for incidental discharges for each facility. The rule includes both new and existing facilities.

B. Local regulatory options -- Proper application of fertilizer and manure could be made cross-compliance requirements under the soil conservation standards of the county farmland preservation standards, but administration and enforcement would be difficult.

C. Nonregulatory options. -- The use of soil tests and the best available research-based information on rates, timing, and methods of nitrogen-fertilizer application can help reduce potential groundwater pollution problems. Intensified educational efforts to encourage farmers to recognize and credit nitrogen from sources other than commercial fertilizer (including livestock waste, whey, and nitrogen fixed by legume crops) will help minimize the potential for increased levels of nitrate pollution from agricultural activities. An additional step would be for the county to work with farmers in a voluntary reporting program to document the types, methods, and amounts of materials applied to fields.

Pesticide Storage, Handling, and Use

A. State authorities -- Using a pesticide in a manner inconsistent with application instructions on its label is illegal. The DATCP regulates pesticide use. Chapter Ag 29, Wis. Administrative code, is the primary source of pesticide regulations. The 1983 Wisconsin Act 410 mandates the DATCP to identify pesticides with the greatest potential for contaminating groundwater. The DATCP works with the DNR and the DHSS to establish groundwater standards and preventive action limits for these substances (chap. Ag 161, Wis. Administrative Code). The rule governing bulk storage of pesticides (chap. Ag 163, Wis. Administrative Code) parallels that of fertilizer bulk storage. It includes liquid pesticide in containers larger than 55 gallons or solid pesticide in undivided quantities greater than 100 pounds. Chapter Ag 29, Wis. Administrative Code, governs the disposal of pesticide containers, residual pesticides, or rinse water.

B. Local regulatory options -- The regulatory role of local government in regard to pesticide storage, handling, and use should be clarified in the statutes and administrative rules. Under certain circumstances, for example, in well-protection areas, additional local controls may be warranted.

C. Nonregulatory options -- Research has shown that a substantial number of private applicators are not calibrating pesticide application equipment accurately. A county can intensify its efforts to educate applicators in properly maintaining and calibrating their equipment. Substantial progress has been made in developing integrated pest management (IPM) practice recommendations for some major crops. Efforts to advise farmers of these recommendations should continue. When possible, field days and demonstrations of IPM scouting procedures should be conducted and information on the availability of IPM scout services should be supplied to farmers.

Irrigation

A. State authorities -- The DNR regulates irrigation wells with a capacity of more than 100,000 gallons per day (chaps. 144 and 162, Wis. Statutes, chap. NR 112, Wis. Administrative code) and requires that back-flow preventor valves be installed and inspected annually when fertilizers and pesticides are injected and applied through the irrigation system. However, no coordinated program insures that this inspection is conducted. The DNR must be notified when a back-flow preventor is installed.

B. Local regulatory options -- County authority to develop local inspection programs is unclear. A potential source of authority is found in the powers given to the county to adopt a sanitary code under sec. 59.07(51), Wis. Statutes.

C. Nonregulatory options -- The UW-Extension has developed an irrigation scheduling program and research has been conducted on how much production will be increased under irrigation. Soil-test recommendations have been modified in light of the additional nutrient needs of crops managed for higher levels of production. Educational efforts to inform and advise farmers of the latest irrigation scheduling findings and nutrient recommendations should continue.

Hazardous Waste

A. State authorities -- Sections 144.60 to 144.74, Wis. Statutes, set the state hazardous-waste management policy. Hazardous waste is defined in sec. NR 181.12, Wis. Administrative Code, as a solid waste that is either listed as a hazardous waste under sec. NR 181.1(e) or meets one or more of the hazard characteristics under sec. NR 181.15. The rules (chap. NR 181, Wis. Administrative Code) permit transportation, storage, treatment, and disposal of hazardous waste only by licensed operators and encourage reuse and reduction of hazardous wastes. DNR can prohibit methods of treatment or disposal to protect public health and safety and environment. The recently enacted federal program for small generators, which applies to those who generate between 100 and 1,000 kg (2,200 lbs) of waste per month, greatly increases the number of generators subject to the law. DNR created a third category which includes those who generate less than 100 kg per month, excluding households.

B. Local regulatory options -- The need for local government to regulate the storage and handling of small amounts of hazardous waste is eased by the existence of the state and federal small-generators program. Small amounts of waste could be regulated as a part of a local hazardous substance and hazardous waste ordinance.

C. Nonregulatory options -- Local government could assist small generators by providing a place for temporary storage. This would facilitate economies of scale in waste disposal.

Hazardous Materials

A. State authorities -- There is an important distinction, in regulatory terms, between hazardous waste and hazardous substances. State regulations apply primarily to hazardous waste, i.e., materials no longer usable for their originally intended purpose or discarded materials. Some hazardous substances are regulated at the state level in the Wis. Administrative Code rules for fertilizer bulk storage (chap. Ag 162), pesticide bulk storage (chap. Ag 163), storage of petroleum (chap. ILHR 10), engine waste collection, storage, and transportation (chap. NR 183), and spills of hazardous substances (chap. NR 158). Many hazardous substances remain unregulated at the state level.

B. Local regulatory options -- It might be desirable to control the storage and handling of hazardous substances not regulated by the state at the local level. Mandating a state-level reporting system that would distribute this information to local governments has been proposed in the legislature. These proposals do not establish standards for storage or handling, although state technical standards would be desirable. Close coordination with state agencies and obtaining technical assistance would be essential.

C. Nonregulatory options -- An educational program for enterprises handling and storing hazardous materials could be conducted in conjunction with a program for households.

Household Hazardous Materials

A. State authorities -- Chapter NR 181, Wis. Administrative Code, exempts household wastes from the hazardous waste rules, unless they are segregated and accumulated by someone other than the homeowner. Household waste can be disposed of by home owners at solid waste disposal sites.

B. Local regulatory options -- Local governments could probably require household hazardous materials to be safely stored, handled, and disposed of, but inspection and enforcement would be difficult.

C. Nonregulatory options -- Conducting public education programs and facilitating disposal of hazardous household materials is a more realistic approach for local governments. An informational component of the county groundwater protection program can include educational materials (brochures, newspaper articles) describing how to properly handle and dispose of household hazardous materials. Periodically, local government can organize "Operation Clean Sweep"-type projects. These projects encourage citizens to bring unused hazardous materials to a centralized location. Local governments can contract with a licensed hazardous-waste hauler for safe disposal. Costs for Operation Clean Sweep projects, however, have been high in terms of number of people served and amounts of hazardous waste disposed of.

Petroleum Products Storage

A. State authorities -- Currently the state regulates above-ground and underground tanks used to store flammable and combustible liquids (chap. ILHR 10, Wis. Administrative code). The state has no authority over oil pipelines, but the Public Service Commission regulates natural-gas pipelines. The federal government is presently examining the adequacy of standards for hazardous-liquid pipelines. Therefore, it is difficult for the state or county to act in its own right.

B. Local regulatory options -- City, village, and town fire chiefs administer the rules as DILHR designated deputies. Local government can adopt additional regulations that do not conflict with DILHR technical standards.

C. Nonregulatory options -- Local government can establish an inventory program to complement state programs. Besides inventorying the location of tanks, their contents, age, and construction material, local government can establish a program to monitor tanks located close to municipal wells and in other sensitive areas. Some of the monitoring sites may be recommended for a state groundwater monitoring program. Local staff can develop information and education materials, primarily brochures and pamphlets, for petroleum products distributors, service station operators, and farmers. These materials should focus on how leaking tanks can pollute groundwater and endanger drinking-water supplies and on how the pollution can be prevented. Staff can also develop a voluntary training program for fire officials and tank inspectors. Local government can encourage voluntary management options such as containment structures, equipment maintenance, operation and safety procedures, and contingency spill plans.

Spills of Hazardous Materials

A. State authorities -- Current Wisconsin law (sec. 144.76, Wis. Statutes) places spills under the jurisdiction of the DNR (chap. NR 158, Wis. Administrative Code). This rule may require contingency plans for emergency response where existing control measures are deemed inadequate. DATCP rules governing the storage, handling, and transport of pesticides (chaps. Ag 29 and Ag 163, Wis. Administrative Code) and fertilizers (chap. Ag 162) also call for the preparation of contingency plans. Preventive controls are included in state laws regulating transportation of hazardous materials.

B. Local regulatory options -- Local government can require contingency cleanup plans for facilities storing and handling hazardous materials under its zoning and other regulatory authority. Local government can set an example by requiring its departmental operations that deal with hazardous materials to develop such plans.

C. Nonregulatory options -- Spill sites in high-risk areas and near municipal and other public water-supply sources can be monitored by local government. The county can help coordinate emergency responses and remedial actions taken by state or local officials. This can include summarizing the results of remedial actions, reporting problems to the state, and mapping spill sites. Information and education materials should describe emergency steps in case of a spill and detail cleanup procedures.

Storage and Use of Salt for Highway Deicing

A. State authorities -- The DOT has established standards for salt storage under the provisions of the state groundwater law (chap. Trans 277, Wis. Administrative Code).

B. Local regulatory options -- Other than self-regulation, local regulatory measures are not warranted.

C. Nonregulatory options -- Since some form of government is responsible for all salt storage and usage, the best tool for controlling potential problems is proper governmental practices. Reduction in road salt usage can be accomplished through more judicious use without significantly impacting highway safety. A monitoring program may be warranted in pollution sensitive areas to determine if storage or salt use has affected groundwater.

Water Wells

A. State authorities -- The DNR regulates private well construction and abandonment (chap. NR 112, Wis. Administrative Code) and also requires well drillers to be registered. Provision for county administration of well regulations is spelled out in chap. NR 145, Wis. Administrative Code. Municipalities are required to maintain public well water quality standards (chap. NR 109, Wis Administrative Code) and to develop ordinances regulating the proper abandonment of all unused or unsafe wells within their water service areas (sec. NR 111.26, Wis. Administrative Code).

B. Local regulatory options -- Before deciding to administer a well code program, a county should review the DNR county well code program requirements. Chapter NR 145, Wis. Administrative Code, describes four alternative degrees of involvement (delegation levels) a county can choose if it wishes to administer the code:

1) Level 1 - Private well location--Issuing location permits, inspecting wells, and requiring the abandonment of wells.

2) Level 2 - Well location and pump installation--Includes level 1 and issuing pump installation permits.

3) Level 3 - Existing private water systems--Includes level 1 and inspecting existing systems.

4) Level 4 - Private well construction--Includes levels 1 to 3 and ensuring compliance with chap. NR 112 well construction requirements.

C. Nonregulatory options -- By educating the public about water quality, citizens will realize that land-use activities can impact the quality of their drinking water. Information concerning routine testing of private wells in rural areas can help people ensure their water is free from contamination by bacteria and nitrate.

Chapter VIII.

GROUNDWATER PROTECTION STRATEGIES AND ALTERNATIVES-- DECIDING WHAT TO DO

Considering the Risks

In deciding what sources of groundwater pollution should be controlled, a local government needs to consider the size of the population potentially "at risk"; the toxicity of particular pollutants and their probable health effects; and the geographic extent of the area or aquifer affected by pollution. Answers to these questions will help local officials decide on local priorities, for example, focusing on septage disposal and handling of hazardous materials versus pesticide management.

The bottom line concern in groundwater quality management is public health. In general, any pollutant can lead to disease or death if it becomes highly concentrated within the body. Many factors influence the level of exposure to pollutants, e.g., where we live, what we consume, and how old we are. Determining the risks associated with a groundwater pollutant is very complex.

Risk assessment is the scientific process of estimating the threat that chemicals pose to human health. Scientists generally base risk assessments on health effects data from animal experiments conducted at exposure levels much higher than those found in the environment. In addition to these toxicity studies performed on laboratory animals, data from accidental human exposure are also used. The data base is often less than desirable, and interpretations can be controversial. Predicting the effects of many chemicals on human health is difficult because the linkages between exposure and diseases such as cancer are poorly understood. Thus, answers to the question "How safe is safe enough?" can be uncertain. Even the issue of determining the population at risk is difficult because the health risk depends partly on the existing health status of an individual.

Risk assessment can estimate the degree of risk presented by a particular chemical, however, it cannot tell whether that risk is acceptable. A number of methods have been developed to help weigh the risks. Risk management tries to balance the scientific assessment of health effects with social costs and benefits. Because of the complexities and uncertainties associated with risk assessment, the federal, and in some cases state governments, have assumed the responsibility of developing regulations and standards that reduce exposure to a level of acceptable risk. This in effect, defines "safe" drinking water. Local governments are preempted in this arena.

Even the most elaborate risk assessment and management schemes demand careful scrutiny as does assessing the severity of groundwater pollution sources. While local, state, and federal health officials can provide information on regulatory standards (where they exist) and health effects, local officials must determine the significance of pollution occurrences and sources in order to improve a program's priorities and direction. These are tough, but not unusual, choices to make. Our daily lives are filled with risks, far beyond the questions associated with "safe" water and groundwater protection. For example 50,000 people die annually in car accidents, yet people continue to drive and derive personal benefit from their cars. There are dangers associated with skiing and canoeing, but we elect to assume the risks in order to enjoy these sports. These are voluntary risks, in contrast to consuming water--a necessity which may expose people to some degree of involuntary risk. Estimated drinking-water risks are generally less than many everyday accidental causes of death. Groundwater protection efforts should reflect our best thinking at the time a decision is made, although ideas may change as new information becomes available.

Selecting Groundwater Protection Strategies

Selecting a course of action involves making choices. There is no formula available to guarantee making the right choice and a good course of action for one local unit may not be appropriate for another. The variability in natural resources, perceptions of groundwater problems, political traditions, and management and fiscal capabilities suggest that different counties might elect to follow quite different groundwater protection paths. Dane, Marathon, and Portage Counties have chosen to pursue relatively comprehensive groundwater protection planning efforts. In contrast, Barron County has moved ahead selectively to address possible groundwater pollution caused by animal waste and has adopted an animal-waste management ordinance. Whatever local governments do, however, must agree with the fundamental state responsibility and laws for water quality management.

Remedial v. Preventive Actions

Determining to what degree actions will be remedial v. preventive is among the first decisions to be made when selecting groundwater protection strategies. The discovery of groundwater pollution is often the event that triggers citizen concern and demands governmental action. In responding, local officials must weigh the costs and effectiveness of addressing the momentary crisis against preventing such problems in the first place. The group that responds to a contamination problem by developing a "cleanup" program may face an unending task. Although technologies exist for restoring many groundwater aquifers (in most cases soil removal or pumping and treatment will eventually clean up polluted groundwater), these can be both lengthy and extremely expensive. The high costs and limited efficiency associated with remedial efforts underscores the value of preventive approaches. Thus, remedial efforts should be undertaken within a broader context of preventing or limiting reoccurrences of the problem.

All Pollution Sources v. Selectivity

A second critical factor relates to the scope of the management initiatives. Should a groundwater protection program be targeted at all polluting sources or should it be selective? Many local programs will have a modest beginning that may reflect limited technical or financial resources or the lack of immediate need for a more comprehensive program. In contrast, a more comprehensive effort may be essential when the nature of the groundwater problems demands action on a number of fronts. Thus, as noted in Chapter II, one effort might be initially limited to educating farmers on how to better manage animal waste, while another might call for a broad array of tools and be targeted at multiple rural and urban sources of groundwater pollution. Whether the local program is single- or multi-pronged, it is important to address the most critical sources first.

General Focus v. Special Management Areas

Local government should also decide whether to deal with polluting sources generally, wherever they occur, or whether to focus on special management areas. An advantage of managing groundwater at the local level, in conjunction with state programs, is that local geologic and socioeconomic variability can be considered. Areas are different and need tailor made management approaches to prevent or solve groundwater problems. A management plan with an areal focus could address groundwater pollution in a defined area. For example, the program could consider an area's natural vulnerability to pollution or it could be targeted at all the areas within the jurisdiction that contribute groundwater to public water supplies.

Long-Term v. Short-Term Actions

The element of time needs to be considered when selecting among the actions to be taken. Actions that are short-term in nature, in terms of time to implement them and in duration of their effects need to be defined. What actions should be integrated as short-term first steps within a long-term program needs to be asked. In addition, long-term actions that can be identified, but implemented in stages over many years need to be addressed. A local management program could be broken down and schedules developed for operating and programming purposes.

Regulatory v. Nonregulatory Measures

Decisions should also be based on the degree to which actions are regulatory or nonregulatory in character. Obviously, there are pros and cons associated with differing approaches. Who among us wishes to be further regulated? It is important to remember that while one entity is burdened by regulation, another is protected from damages or unfair actions. Thus, selecting among the mix of tools to tackle groundwater protection should reflect past experience, the nature of affected interests, and the likelihood of achieving the program goals.

These risk and strategy considerations must be weighed as concerned governments grapple with making the correct decisions to protect their groundwater. From the large and often complex "menu" of alternative tools and strategies, local officials can select options likely to be most effective and politically acceptable in achieving local groundwater protection objectives.

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Appendix A. WISCONSIN GROUNDWATER

CONTENTS

FIGURES

TABLES

Appendix A. WISCONSIN GROUNDWATER

Because groundwater and the materials through which it flows cannot be seen, much misunderstanding exists about its occurrence and movement. There is a lot we don't know about groundwater because it is difficult to observe and measure. There is, however, nothing mysterious about groundwater; its occurrence and movement is governed by natural laws, and therefore, its behavior is predictable. Knowledge of hydrogeologic conditions is a requisite for a sound groundwater management program. Understanding the properties and behavior of groundwater and the framework within which the water flows will allow a better understanding of the entry of pollutants to groundwater and their behavior within the groundwater system. This appendix describes the overall hydrogeologic conditions and main groundwater problems in Wisconsin and discusses how your county fits into this broader state picture.

Wisconsin Aquifers

Wisconsin has thick sequences of permeable deposits that form important groundwater reservoirs. These layers comprise four major aquifers: 1) sand and gravel, 2) eastern (Silurian) dolomite, 3) upper sandstone, and 4) lower sandstone aquifers (fig. A1). Locally, the Maquoketa shale and Precambrian rocks are minor aquifers that are used when other aquifers are absent or yield poor-quality water.

The sand-and-gravel aquifer is nearest the land surface and covers most of the state, except for the Driftless Area of southwestern Wisconsin (fig. A1). It is not a continuous rock unit, as are the bedrock aquifers, and consists of discontinuous layers and lenses of highly permeable sand and gravel deposited above, within, or beneath other less permeable unconsolidated deposits that cover more than 75 percent of the state. Surficial deposits in Wisconsin vary greatly in thickness and composition within short distances. Depth to bedrock ranges from zero to more than 500 feet (Trotta and Cotter, 1973). Thicknesses greater than 400 feet occur in the deep preglacial valleys of the Rock, Yahara, and Wolf Rivers and on the Bayfield Peninsula. These deposits consist of Pleistocene glacial and fluvial deposits (till and outwash) and of weathered and disintegrated bedrock material and alluvial deposits of Recent age. Till, deposited during the several advances of continental ice sheets (about 10,000 to 30,000 years ago), consists of unsorted and unstratified clay, silt, sand, and gravel, including boulders. Outwash, deposited by meltwater streams beyond active glacier ice, consists largely of sand and gravel with some cobbles, boulders, and silt and is well sorted and stratified. When the glaciers receded, silt-sized material called loess was deposited by the wind on top of the till and outwash, usually to depths of 1 to 3 feet.

The sand-and-gravel is the principal source of domestic water supplies in northern and south-central Wisconsin. Individual well yields vary widely, from 10 to 1,000 gallons per minute (gpm). The most productive sand-and-gravel aquifers can be found in deep bedrock valleys scattered throughout the state, in the Central Sand Plain, and in northeastern and south-central Wisconsin (Zaporozec and Cotter, 1985).

The eastern (Silurian) dolomite aquifer is an important source of domestic supplies in eastern Wisconsin. It underlies less than 10 percent of the state (fig. A1). It is essentially the sole source of groundwater in the Door Peninsula, where Pleistocene deposits are thin, and in some areas along lakes Michigan and Winnebago where the water from the underlying sandstone aquifer may be saline and the overlying Pleistocene deposits unproductive. Well yields range from 10 to 500 gpm, and in places more. The eastern dolomite aquifer, which includes dolomite of Silurian and Devonian age, thickens eastward, with a maximum thickness of about 600 feet along the Lake Michigan shoreline. The Niagara escarpment, a prominent topographic ridge, forms its western edge. Wells drawing water from this aquifer must penetrate the overlying unconsolidated deposits, which vary in thickness from zero (where the dolomite outcrops in Door County) to more than 200 feet in southeastern Wisconsin.

Generalized Geologic Section of Wisconsin Aquifers

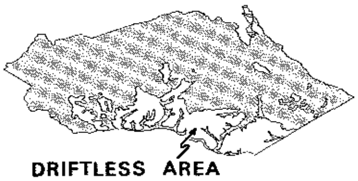
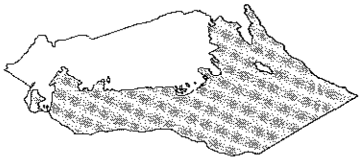
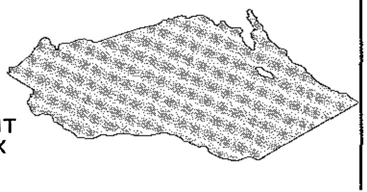
SYSTEM	GEOLOGIC UNIT	DOMINANT LITHOLOGY	AQUIFER
QUATERNARY	HOLOCENE ALLUVIAL AND PLEISTOCENE GLACIAL DEPOSITS	UNCONSOLIDATED SAND AND GRAVEL; VARIABLE AMOUNTS OF SILT, CLAY AND ORGANIC MATERIAL	SAND AND GRAVEL 
DEVONIAN	UNDIFFERENTIATED	DOLOMITE AND SHALE	SILURIAN DOLOMITE 
SILURIAN	UNDIFFERENTIATED	DOLOMITE	
ORDOVICIAN	MAQUOKETA SHALE	SHALE	MAQUOKETA SHALE 
	GALENA DOLOMITE, AND DECORAH AND PLATTEVILLE FORMATIONS; UNDIFFERENTIATED	DOLOMITE	GALENA-PLATTEVILLE
	ST. PETER SANDSTONE	SANDSTONE	
	PRAIRIE du CHIEN GROUP	DOLOMITE	SANDSTONE  **UPPER**
CAMBRIAN	CAMBRIAN SANDSTONES, UNDIFFERENTIATED	SANDSTONE	**LOWER**
PRECAMBRIAN	LAKE SUPERIOR SANDSTONE AND LAVA FLOWS	SANDSTONE AND SHALE, BASALT	PRECAMBRIAN AQUIFER LAKE SUPERIOR SANDSTONE AND LAVA FLOWS 
	IGNEOUS AND METAMORPHIC ROCKS	GRANITIC AND METAMORPHIC ROCKS	BASEMENT COMPLEX 

Figure A1. Generalized geologic section and location of Wisconsin aquifers (adapted from Kammerer, 1981)

The upper sandstone aquifer underlies about 40 percent of Wisconsin. It is present in the western, southern, and eastern parts of Wisconsin and has a maximum thickness of about 600 feet. The overlying layers range in thickness from 0 to more than 900 feet. The aquifer consists primarily of Ordovician dolomite with some sandstone layers. The Galena-Platteville dolomite unit is the uppermost bedrock formation in southern and most of eastern Wisconsin, and is sometimes recognized as a separate aquifer (fig. A1). The upper sandstone aquifer is separated from the lower sandstone aquifer by a less permeable layer of dolomite. It is an important source of domestic water supplies west of the Niagara escarpment and in south-central and southwestern Wisconsin. Well yields range up to 100 gpm.

The lower sandstone aquifer underlies 75 percent of Wisconsin. It is absent over the Precambrian arch in north-central and northwest Wisconsin. The rocks making up this aquifer dip away from this arch and thicken to the east, south, and west. Cambrian sandstone is the prevailing rock type. The sandstone sequence is sometimes interspersed with layers of dolomite, shale, or siltstone. The aquifer has a maximum thickness in southwest Wisconsin of more than 2,000 feet. The top of this aquifer is deeply buried in eastern Wisconsin, and overlying rocks are as much as 1,200 feet thick.

The lower sandstone aquifer is the major source of water throughout its entire limits within the state. The ability of the Cambrian sandstone to store and yield large quantities of water makes it the principal source of water for municipal and industrial supplies. Well yields vary between 15 and 1,000 gpm. The lower sandstone aquifer is the most heavily pumped aquifer in the state. Municipal and industrial wells pumping large amounts (more than 500 gpm) from Cambrian sandstone have caused a gradual decline of artesian pressure in the Green Bay-DePere, Milwaukee-Waukesha, Kenosha-Racine, and Madison metropolitan areas.

Precambrian rocks are not a major source of groundwater in Wisconsin relative to other aquifers. They form a "basement" under the entire state and are normally not used as a source of water because they are either too deep or overlain by productive layers of younger sediments. When needed, the Precambrian crystalline, granite-like rocks locally yield up to 20 gpm, although some yields of more than 100 gpm have been documented from fracture zones (Socha, 1983 and WGNHS files). This aquifer is used in north-central Wisconsin. In extreme northwest Wisconsin a sequence of Precambrian sedimentary rocks (Lake Superior sandstone) overlying the crystalline rocks is a regionally productive aquifer (fig. A1). Wells in the sandstone have been pumped at 500 gpm, and the average high-capacity well yield is 180 gpm (Young and Skinner, 1974).

More than one million billion gallons of groundwater is estimated to be stored in Wisconsin aquifers (Holt, 1975). At current pumping rates for private, municipal, agricultural, and industrial uses, groundwater in storage would last approximately 5,000 years without replenishment. However, groundwater in Wisconsin is being replenished constantly. About 16 billion gallons of water is recharged every day, while only 600 million gallons of groundwater is being withdrawn (Holt, 1975).

Groundwater Use

The first, basic step in a groundwater management planning process is to establish a need for it. We have to answer the question: "Is the groundwater important enough to Wisconsin water supplies that it must be protected"? The importance of groundwater to Wisconsin's total water supply can be documented by analyzing water-use data.

During 1979 (the last year for which detailed data are available), Wisconsin water users withdrew nearly 1,240 million gallons per day (mgd) of ground and surface water (Lawrence and Ellefson, 1982). This value does not reflect water used for generating thermoelectric and hydroelectric power, which by far is the largest of all uses. Water used for power production, however, is largely taken from surface water sources and is returned after use. Figure A2 shows water use for the five major use categories: public supplies, private supplies, self-supplied industry and commerce, agriculture, and generation of electrical power. Table A1 lists, by category, those counties that withdrew more than 1 mgd of groundwater for individual uses in 1979.

Groundwater provided 603 mgd (48.7%) and surface water supplied 635 mgd (51.3%) for the first four categories shown in figure A2. Groundwater is a primary source of water for agriculture, the sole source of rural water supplies, and a very important source of public supplies. Almost all the water (more than 97%) consumed for rural uses (domestic supplies, stock watering, and irrigation) comes from groundwater sources. More than 90 percent of Wisconsin communities use groundwater. Only the larger communities along lakes Michigan, Superior, and Winnebago use primarily surface water for their municipal water supplies.

Figure A3 illustrates the reliance of individual counties on groundwater. In 1979, more than 75 percent of Wisconsin counties used more groundwater than surface water for their supplies, and in 47 counties groundwater accounted for more than 90 percent of the total water use.

Total withdrawals of groundwater in 1979 (fig. A4) generally followed the distribution of population density (fig. A5). However, when compared with population density, some counties withdraw large amounts of groundwater in relation to their population density. These include agricultural counties (Adams, Portage, and Waushara) where groundwater is used for irrigation and stock watering, or industry-oriented counties (Chippewa and Rock), which use large quantities of groundwater for industrial purposes. On the other hand, some counties withdraw small amounts of groundwater relative to their population density. These counties (Brown, Kenosha, Manitowoc, Outagamie, Racine, and Winnebago) depend primarily on surface water for municipal supplies.

The amounts of groundwater withdrawn indicate that Wisconsin groundwater resources are largely underutilized. It has been estimated that between 3 and 33 percent of precipitation may infiltrate and recharge Wisconsin aquifers. The infiltration of precipitation is, of course, highly variable, depending on the permeability of soil and rock

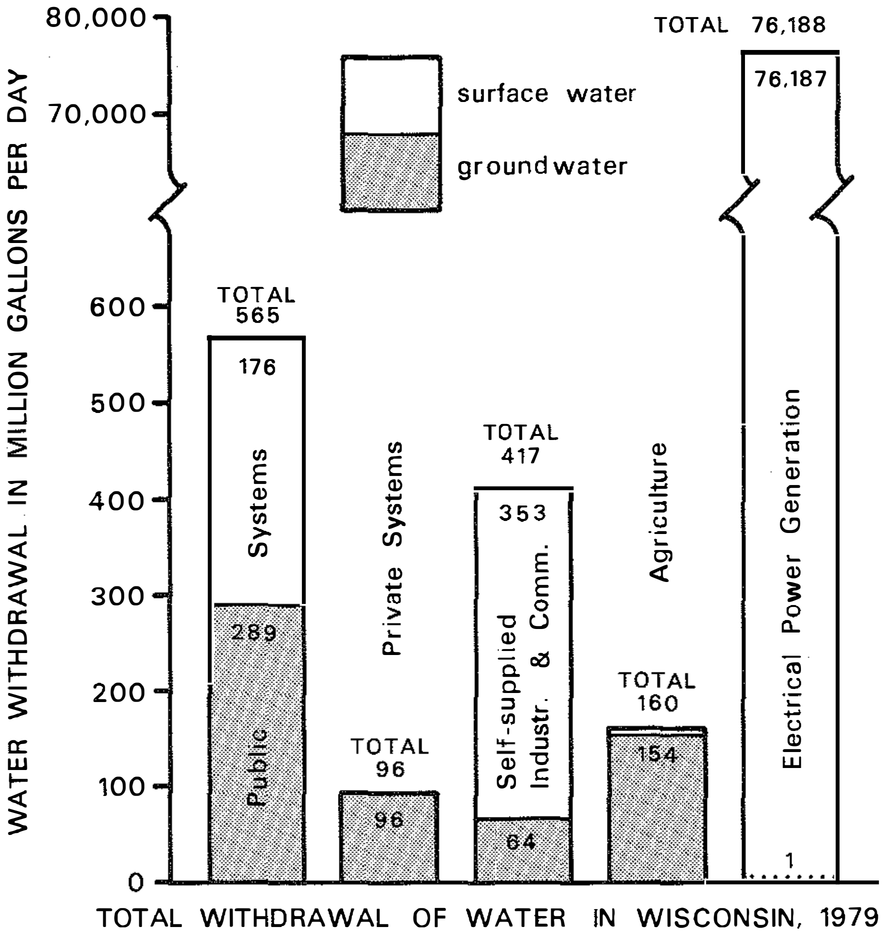


Figure A2. Total withdrawal of water in Wisconsin, 1979 (data source, Lawrence and Ellefson, 1982).

Table A1. Use of groundwater in Wisconsin in 1979, over 1 mgd
(data source, Lawrence and Ellefson, 1982)

No.	Resident municipal		Industr. municipal		Industr. self-suppl.		Commerce		Irrig.		Stock		Other	
	Co.	mgd	Co.	mgd	Co.	mgd	Co.	mgd	Co.	mgd	Co.	mgd	Co.	mgd
1.	Dn	16.7	Mr	6.8	Dn	6.9	Dn	6.8	Pt	27.4	Gr	3.4	Dn	13.4
2.	Wk	7.7	Bn	6.4	Pt	6.4	LC	3.9	Ws	14.6	Mr	2.9	LC	8.8
3.	Ro	7.3	Wk	6.2	Ml	6.3	Wk	3.5	Ad	11.5	Dn	2.8	Ro	6.2
4.	LC	3.4	LC	4.7	Je	3.3	Ro	3.3	Du	3.2	Ck	2.4	La	5.6
5.	EC	3.1	Dn	4.5	Wk	3.2	Mr	1.7	Iw	3.2	Gn	2.1	FL	4.9
6.	Bn	3.0	EC	4.4	Wi	2.9	Bn	1.5	Sk	3.1	Lf	2.1	Wk	4.6
7.	Mr	2.7	Ro	3.7	Dg	2.8	EC	1.5	Ro	2.1	Fl	1.9	Pk	3.8
8.	FL	2.6	Je	3.0	LC	2.6	Ww	1.5	Ju	2.0	Br	1.8	Ba	3.3
9.	Je	2.2	Wp	3.0	Ou	2.2	Je	1.3	Wp	1.4	Ch	1.8	Je	3.1
10.	Wd	1.9	Wn	2.4	Bn	2.1	Dg	1.2	Dn	0.9	Iw	1.8	EC	3.0
11.	Dg	1.8	Ch	2.2	FL	2.0	FL	1.2			Sk	1.8	Bn	2.2
12.	Ww	1.8	FL	1.8	Ro	1.8	Wd	1.2			Ve	1.8	Ws	2.2
13.	Ou	1.7	Dg	1.6	Sb	1.5	Ds	1.0			Du	1.7	Mr	2.1
14.	Ra	1.6	Ds	1.6	Br	1.4					Ou	1.7	Pt	1.9
15.	Oz	1.4	Oz	1.6	Ja	1.4					Sh	1.7	Ww	1.9
16.	Co	1.3	Wd	1.6	Tr	1.4					Mn	1.6	Wd	1.6
17.	Ds	1.3	Ca	1.4	Mr	1.2					Dg	1.5	Dg	1.5
18.	Gr	1.3	Sb	1.4	Wd	1.1					SC	1.5	Wn	1.4
19.	Pt	1.3	Ww	1.4	Ca	1.0					Tr	1.5	Br	1.3
20.	Wn	1.2	Ou	1.1							Co	1.4	Ve	1.2
21.	Sk	1.1									Mo	1.4	Gr	1.1
22.											Ro	1.4	Sk	1.1
23.											Bf	1.3	Gn	1.1
24.											Pk	1.3	Ou	1.1
25.											Wp	1.3	Mo	1.0
26.											Pi	1.2		
27.											Ri	1.2		
28.											Oc	1.1		
29.											Sb	1.1		
30.											Ta	1.1		
31.											Kw	1.0		

mgd = million gallons per day

COUNTY CODE

Ad	Adams
Br	Barron
Ba	Bayfield
Bn	Brown
Bf	Buffalo
Ca	Calumet
Ch	Chippewa
Ck	Clark
Co	Columbia
Dn	Dane
Dg	Dodge
Ds	Douglas
Du	Dunn
EC	Eau Claire
Fl	Florence
FL	Fond du Lac
Gr	Grant
Gn	Green
Iw	Iowa
Ja	Jackson
Je	Jefferson
Ju	Juneau
Kw	Kewaunee
LC	La Crosse
Lf	Lafayette
La	Langlade
Mn	Manitowoc
Mr	Marathon
Ml	Milwaukee
Mo	Monroe
Oc	Oconto
Ou	Outagamie
Oz	Ozaukee
Pi	Pierce
Pk	Polk
Pt	Portage
Ra	Racine
Ri	Richland
Ro	Rock
SC	St. Croix
Sk	Sauk
Sh	Shawano
Sb	Sheboygan
Ta	Taylor
Tr	Trempealeau
Ve	Vernon
Ww	Walworth
Wn	Washington
Wk	Waukesha
Wp	Waupaca
Ws	Waushara
Wi	Winnebago
Wd	Wood

material and on geomorphological conditions. It is likely that the average annual groundwater recharge varies from close to zero in parts of eastern Wisconsin, where there are nearly impermeable soils, to perhaps as much as 50 percent of annual precipitation in the central and northern portions of the state, where sandy glacial deposits cover the surface. Moreover, it is likely that recharge varies spatially within a groundwater basin (Anderson, 1987). If we assume that 15 percent of the annual precipitation reaches groundwater, average groundwater recharge in 1979 amounted to 14,400 mgd. Estimated daily use of groundwater in 1979 was 604 million gallons, which is about 4 percent of the total amount of groundwater assumed to infiltrate in that year.

Similar calculations can be done for individual counties, if we estimate the average rate of groundwater recharge for the county. Most Wisconsin counties should have sufficient supplies of groundwater if their demand for groundwater increases. Counties with a high rate of utilization should carefully analyze supply and demand before planning high-capacity water-supply facilities. A technical analysis such as this would require the services of a consultant. Groundwater is most intensively utilized in counties that have either large population, industrial, and commercial centers supplied by groundwater (Dane, La Crosse, Milwaukee, Milwaukee, Ozaukee, Rock, and Waukesha) or extensive irrigation relative to their size (Portage and Waushara). Utilization generally decreases from southeast to northwest.

Wisconsin citizens get their water from public water-supply systems or from individual private wells. In 1985, more than 35 percent of Wisconsin population was served by public water systems supplied by groundwater (USGS, personal communication, 1987) that are classified as community or noncommunity. Community systems supply

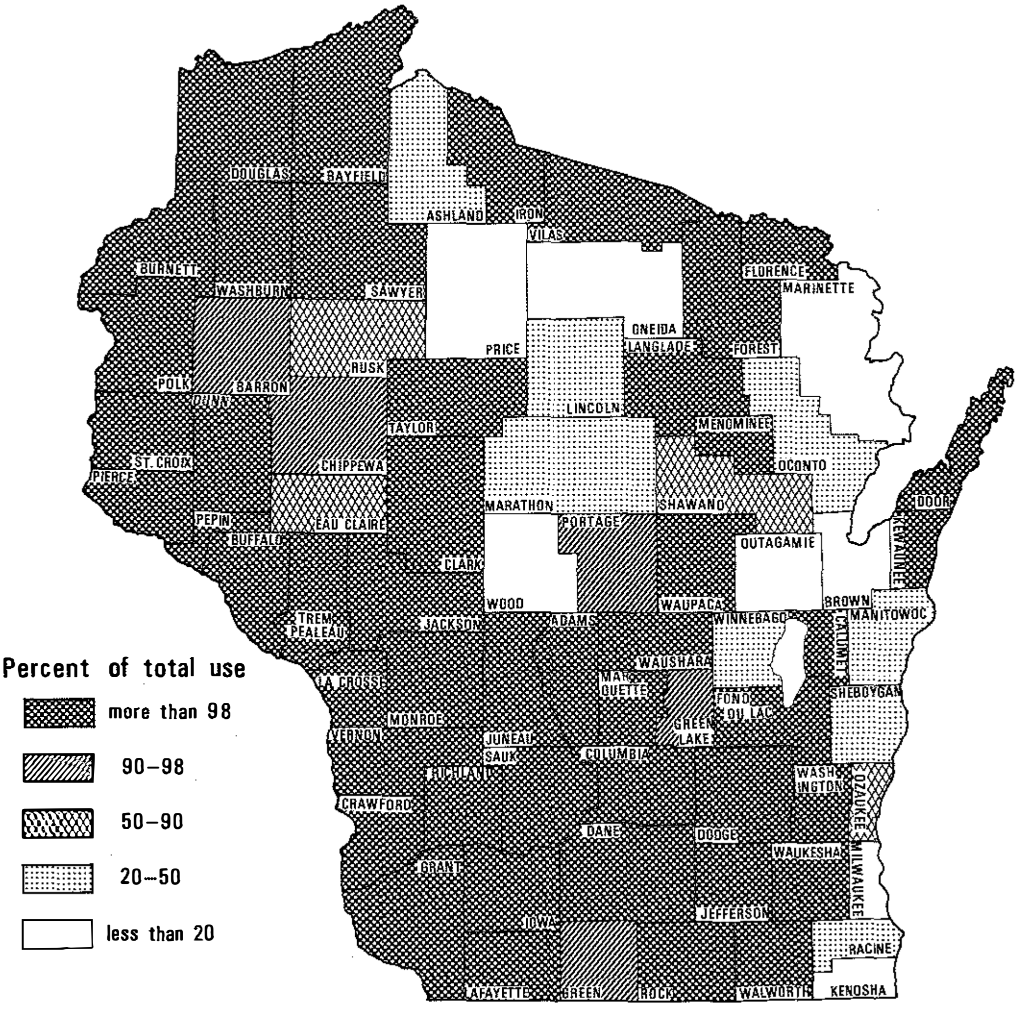


Figure A3. Percent groundwater use relative to total use of water in Wisconsin in 1979, by county (data source, Lawrence and Ellefson, 1982).

water to residents of Wisconsin cities and villages from 1,500 wells and to mobile home parks, subdivisions, and institutions from another 900 wells. A noncommunity public water system serves at least 25 persons per day at least 60 days each year. It largely serves nonresidents, and is typically an individual well that supplies a school, restaurant, service station, tavern, motel, campground, or church. In 1985, there were approximately 13,000 active noncommunity public water systems in Wisconsin. In addition, individual private wells supply commercial establishments and smaller industries and provide water for drinking and livestock watering to rural residencies and farms. There are an estimated 700,000 private wells in Wisconsin. In 1985, the Wisconsin Department of Natural Resources (DNR) had approximately 303,000 well-driller's reports on file. Copies of these reports are also available at the Wisconsin Geological and Natural History Survey (WGNHS).

Natural Quality of Groundwater

The chemical composition of groundwater largely depends on the composition and physical properties of earth materials through which the water moves and on the duration of contact with the materials. Therefore, groundwater from deeper aquifers has higher mineral concentration than water from shallow aquifers, because the water has been in contact with minerals longer. In Wisconsin, groundwater chemistry is a result of water movement through and interaction with unconsolidated materials and sedimentary rocks where materials available for dissolution are calcium and magnesium carbonates. Therefore, groundwater is predominantly of the calcium-magnesium-bicarbonate type.

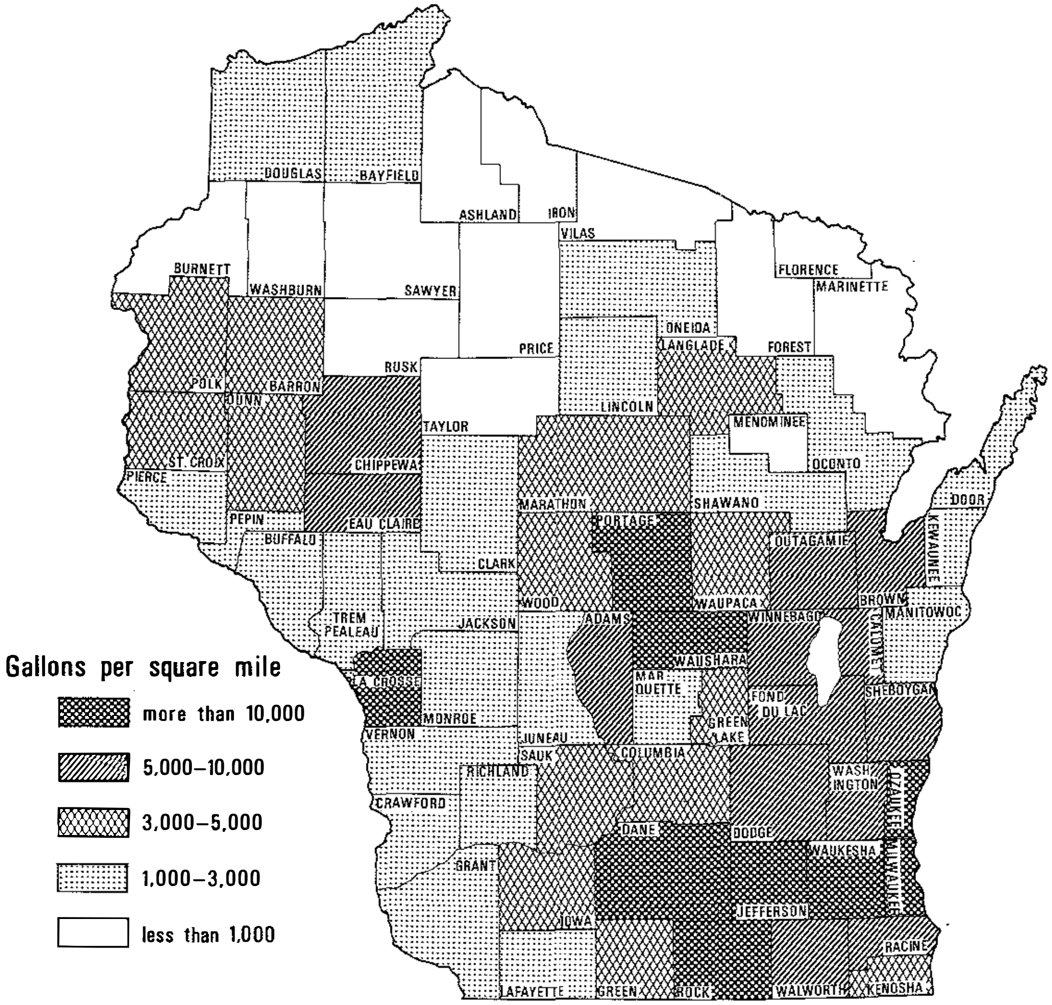


Figure A4. Groundwater use in Wisconsin in 1979, by county, in gallons per square mile (data source, Lawrence and Ellefson, 1982).

Groundwater quality in Wisconsin is good and generally is suitable for most purposes at almost any location in the state. Dissolved solids are usually under 500 milligrams per liter (mg/l) (equivalent unit is parts per million, ppm), but hardness commonly exceeds 200 mg/l and softening of water is required for most purposes (fig. A6). Water from dolomite is especially hard.

Calcium, magnesium, sodium, bicarbonate, sulfate, and chloride normally form more than 95 percent of the total dissolved solids in water. Calcium and magnesium form about one half of all ions in Wisconsin groundwater and are the principal components of hardness. Other common chemical constituents of groundwater in Wisconsin are potassium, iron, manganese, fluoride, silica, and nitrate. Practically all water in the state contains some iron, which can be a problem locally if the concentration is greater than 0.3 mg/l (the recommended limit for drinking water). The areal distribution of iron is unpredictable. Manganese resembles iron in its unpredictable occurrence in water and in its chemical behavior. The concentrations of iron and manganese over recommended limits are objectionable for taste and aesthetic (discoloration) reasons, but they have no adverse effects on human health.

Besides these more abundant elements, groundwater in Wisconsin may contain a number of additional elements, which, if present, are usually found in minute concentrations and which are not routinely analyzed for. They include arsenic, barium, boron, cadmium, chromium, cobalt, copper, cyanide, lead, lithium, mercury, nickel, selenium, silver, strontium, and zinc. These elements, which can occur naturally or be introduced in groundwater by waste disposal, are potentially toxic.

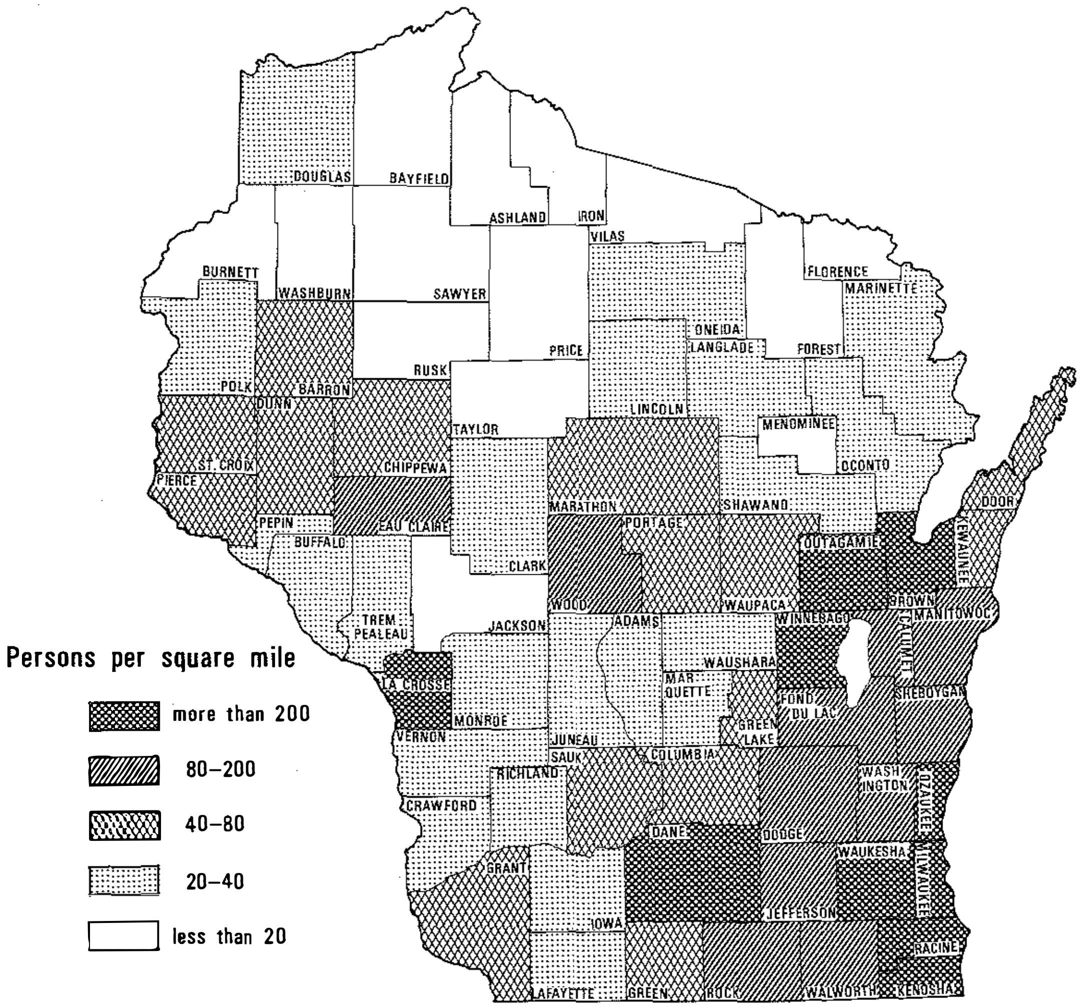


Figure A5. Wisconsin population density in 1980, by county, in persons per square mile (data source, Wisconsin Blue Book, 1981–1982).

Major Groundwater Problems

Water Availability Issues

In 1983, the Wisconsin District Office of the U.S. Geological Survey identified the following water availability problems (U.S. Geological Survey, 1984):

Increasing groundwater pumpage from the sandstone aquifer in eastern Wisconsin has caused large declines in water levels. Groundwater pumpage in Milwaukee, Waukesha, Kenosha, and Racine counties in southeastern Wisconsin has created an extensive cone of depression; water levels have declined more than 100 feet throughout a large area (Erickson and Cotter, 1983). This cone of depression is merging with the cone of depression in the Chicago metropolitan area in northeastern Illinois where water levels have declined more than 850 feet. This is creating tension between the two states (Fetter, 1981).

Municipal and industrial pumpage in the lower Fox River Valley has caused water levels to decline hundreds of feet since pumping began in the 1880s. In 1957, after the city of Green Bay started using water from Lake Michigan, groundwater levels recovered 200 feet at Green Bay. However, water levels are again declining because of increasing industrial and municipal pumping (Erickson and Cotter, 1983).

Progressive declines of groundwater levels in the sandstone aquifer have also accompanied increasing groundwater withdrawals in the Madison metropolitan area. These declines, however, are not as serious as in eastern Wisconsin.

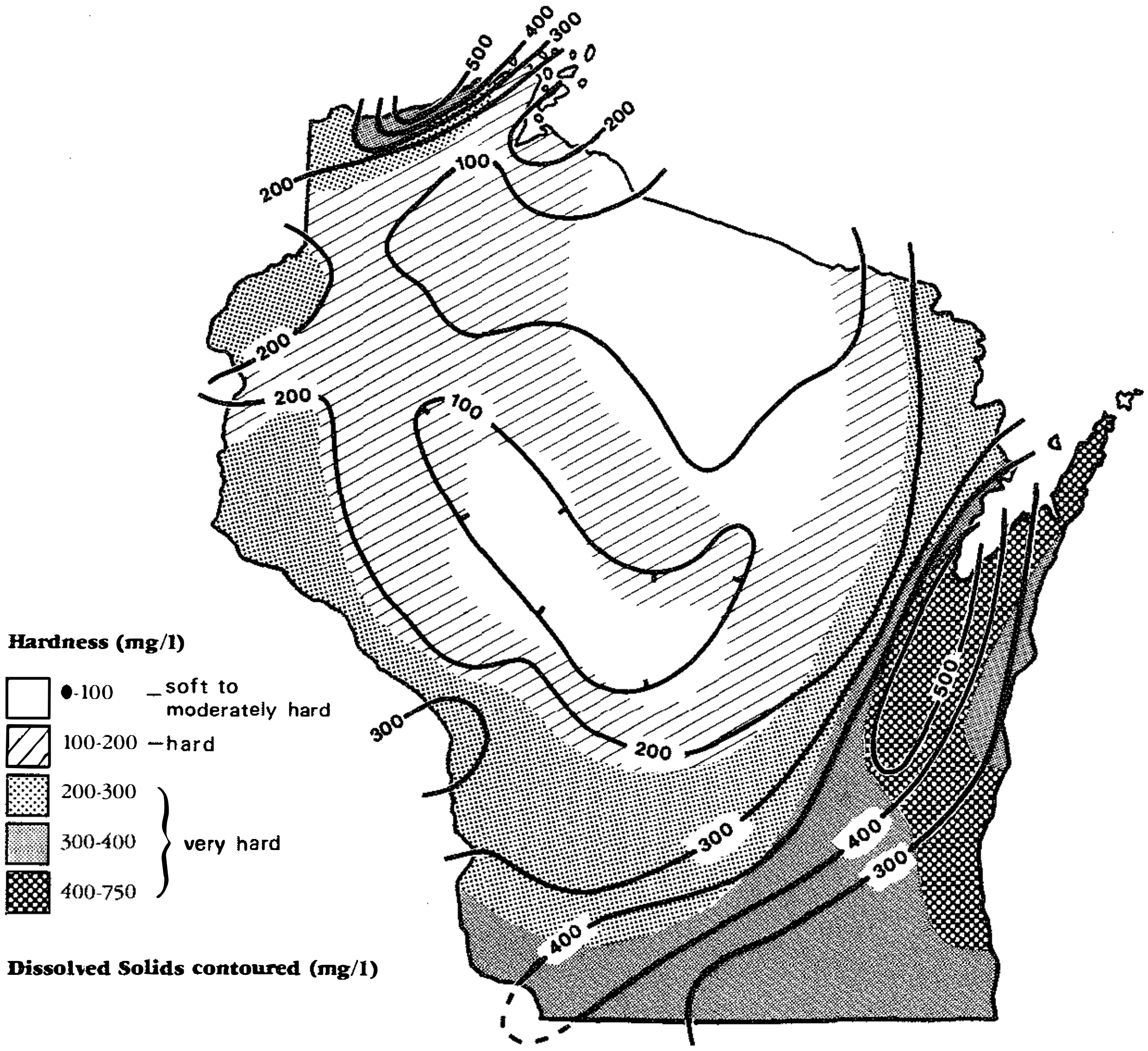


Figure A6. Hardness and dissolved solids of Wisconsin groundwater (modified from Pettyjohn and others, 1979).

The acreage irrigated by groundwater in the Central Sand Plain has been projected to increase substantially. An increase in irrigated acreage will mean lowered water levels, decreased streamflow, higher surface water temperatures, and the potential for groundwater pollution from increased use of fertilizers and pesticides. These may be significant resource management issues in the near future.

Water-Quality Issues

Groundwater quality in Wisconsin is most commonly affected by inadequate waste disposal practices, handling and application of fertilizers and pesticides, improper storage and handling of industrial and agricultural chemicals, spills and leaks of hazardous substances, and improper construction or abandonment of wells (for details see chapter IV).

Wisconsin has an estimated 2,700 abandoned or improperly closed landfills (Bakken and Giesfieldt, 1985). At some of these sites adjacent landowners have pumped polluted groundwater from their domestic wells. The potential for additional pollution is significant because many domestic wells obtain water from shallow water-table aquifers, which are the most susceptible to pollution from landfills. Similarly, numerous municipal, industrial, and private waste-disposal ponds and lagoons throughout the state may be leaking wastes and polluting aquifers (Entine and others, 1983). Recently revised regulations for waste disposal should help minimize groundwater pollution at recently constructed or future sites.

Between 1980 and 1982, the pesticide aldicarb was discovered in well water in central Wisconsin in concentrations exceeding the maximum allowable concentration of 10 parts per billion (ppb) (Entine and others, 1983). This discovery prompted the state to restrict use of the pesticide and to consider the possibility that other pesticides may be present in groundwater. Wisconsin DNR is conducting two pesticide sampling programs (Koth, 1985). One program, initiated in July 1983, includes testing for several of the 31 pesticides commonly used in Wisconsin (excluding aldicarb). As of June 1985, 524 homes and private facilities in 50 counties had been tested. Of these, 57 had detectable levels of various pesticides and 17 exceeded the health advisory level (fig. A7). Atrazine, used primarily on corn, was the pesticide most commonly found. The other program includes aldicarb only. In 1981, the DNR began selective testing of private wells for aldicarb, a pesticide used primarily on potatoes. Out of 1,008 wells sampled in 21 counties, 227 had detectable levels of aldicarb; 93 exceeded the health advisory level (fig. A8). Aldicarb use has been discontinued for 1987 on the basis of a negotiated agreement between the manufacturer and the state.

Its high solubility makes aldicarb a particular threat to groundwater. Results of the monitoring program demonstrate the aldicarb problem specifically in southeastern Marathon County and in Portage County. Aldicarb, however, is evident throughout the Central Sand Plain of Wisconsin (Adams, Juneau, Waushara, and Wood Counties). This region is extensively farmed under irrigation and the highly permeable aquifers underlying the region can be contaminated by aldicarb percolating from the surface. Aldicarb was found under similar conditions in Barron and Langlade Counties.

Other agriculturally related water-quality concerns include animal waste, use of fertilizers, and the disposal of whey--a waste product of the state's large dairy industry. All of these may contribute to increased nitrate concentrations. Nitrate is the most common identifiable pollutant, and increased concentrations create health concerns. An unusually high level of nitrate in well water may indicate pollution from septic systems, fertilizers, animal waste storage facilities, or barnyards. Even when nitrate is not a problem in itself, it may indicate that the water contains harmful bacteria or other pollutants. Nitrate concentrations that exceed the recommended limit of 10 mg/l of nitrate-nitrogen (NO_3-N) can be found in many Wisconsin wells; most of which are private rural water supplies.

The incidence of nitrate concentration exceeding the drinking-water standard is lower for public water supplies. A comparison of two DNR studies from 1980 and 1985 shows that the nitrate concentration has not changed significantly during the last 5 years. Noncommunity public water supply systems in Wisconsin are being periodically sampled for nitrate by the DNR. The first sampling was done during 1979-80, when almost 11,400 systems were tested for nitrate (Wisconsin Department of Natural Resources, 1980). The sampling revealed that 356 (3.1%) noncommunity facilities had nitrate-nitrogen levels of 10 mg/l or greater. In 1985, all noncommunity facilities with detectable levels of nitrate (more than 0.5 mg/l) in 1979–80 were resampled (Strous, 1986). A comparison of the results of the two sampling periods showed no statistically significant trend. Figure A9 shows the location and number of wells in each township that exceeded 10 mg/l NO_3-N during the 1985 survey.

Naturally occurring radioactivity in water from some parts of the sandstone aquifer in Wisconsin exceeds safe drinking-water levels (Hahn, 1984). The source of radiation in groundwater is apparently the natural occurrence of radioactive isotopes of uranium and thorium in rocks. These isotopes disintegrate to produce radium, a potential health hazard when present in groundwater in elevated concentrations.

Elevated radium levels occur mostly in water pumped from deep wells (finished 500 to 2,500 feet below the land surface) in the sandstone aquifer in eastern Wisconsin (fig. A10). Some elevated radium levels have also been detected in relatively shallow wells in other parts of the state. Figure A10 shows locations of community wells in Wisconsin where radium levels exceeded 5 picoCuries per liter (pCi/l) in 1982. This limit is the Wisconsin drinking-water standard for combined radium 226 and 228 (chap. NR 109, Wis. Administrative Code) and it is approximately equal to a body dose of 92 millirems per year of radiation (about two chest X-rays), assuming consumption of 2 liters of water per day (Koth, 1985).

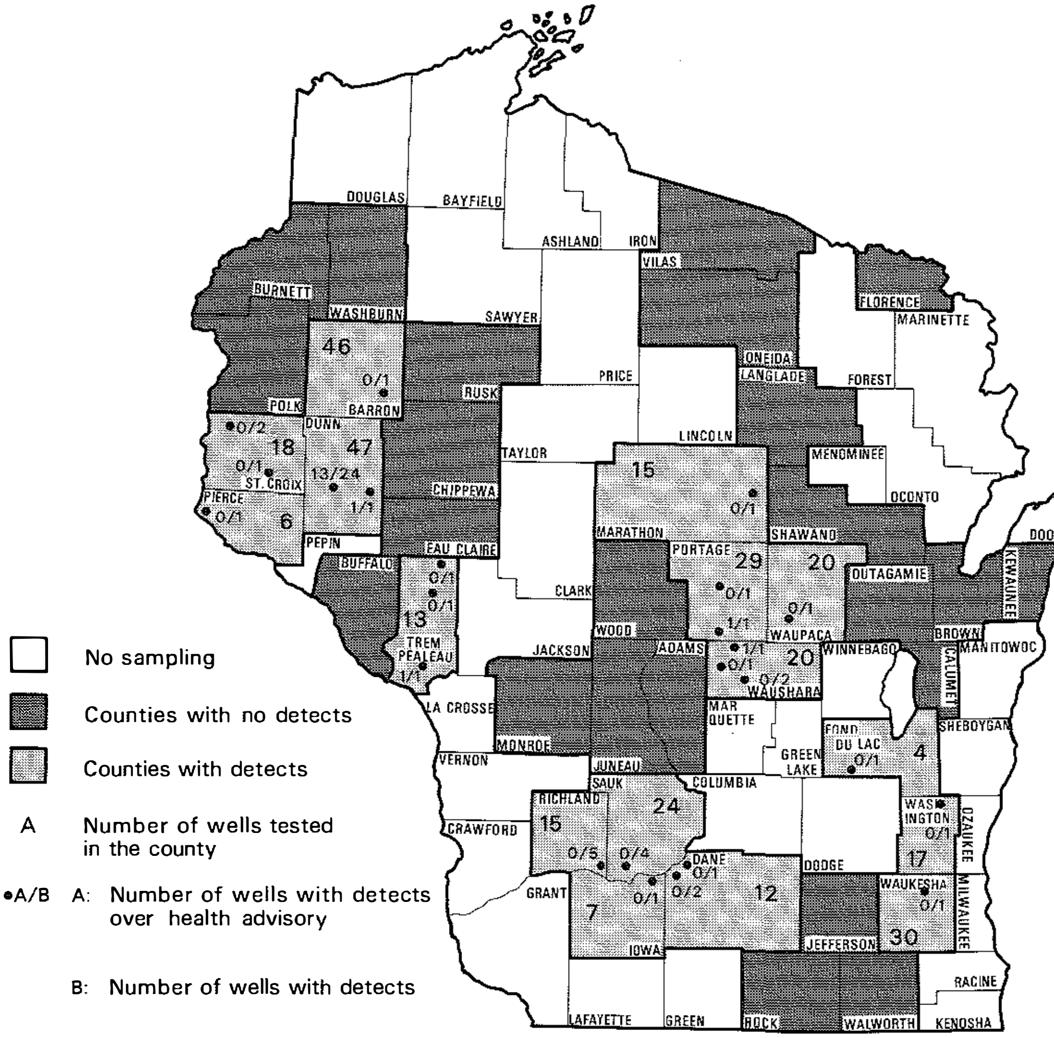


Figure A7. Pesticide sampling program in Wisconsin, excluding aldicarb (from Koth, 1985).

Volatile organic chemicals (VOCs) are another potential health hazard found in Wisconsin groundwater. The major concern is that VOCs enter drinking water primarily through commercial, industrial, and municipal waste disposal. Many of these organics are industrial solvents or household products such as spot and stain removers, paints and thinners, drain cleaners, and air fresheners.

The DNR is presently testing all municipal water-supply systems in the state and up to 600 private wells annually for VOCs. From July 1983 to December 1985, 3,964 wells were tested (Schreiber, 1986). Detects of VOCs are scattered throughout the state and are not limited to any specific area (fig A11). The most commonly found VOC was trichloroethylene (TCE), which is primarily used in industry for degreasing metal parts and for dry cleaning. Domestic uses include spot removers, rug cleaners, and air fresheners.

The bacteriological quality of groundwater is another important aspect of a management program. Although public awareness and concern about toxic contaminants in groundwater have escalated in recent years, bacteriologically unsafe wells continue to be the most common well-contamination problem in Wisconsin. Bacteriologically unsafe wells can be caused by unsatisfactory well or pump installation, cracked casing, or improper grouting. Drinking water can also be contaminated by cross-connection between contaminated water (wash tub, garden house, bathroom facilities, etc.) and plumbing.

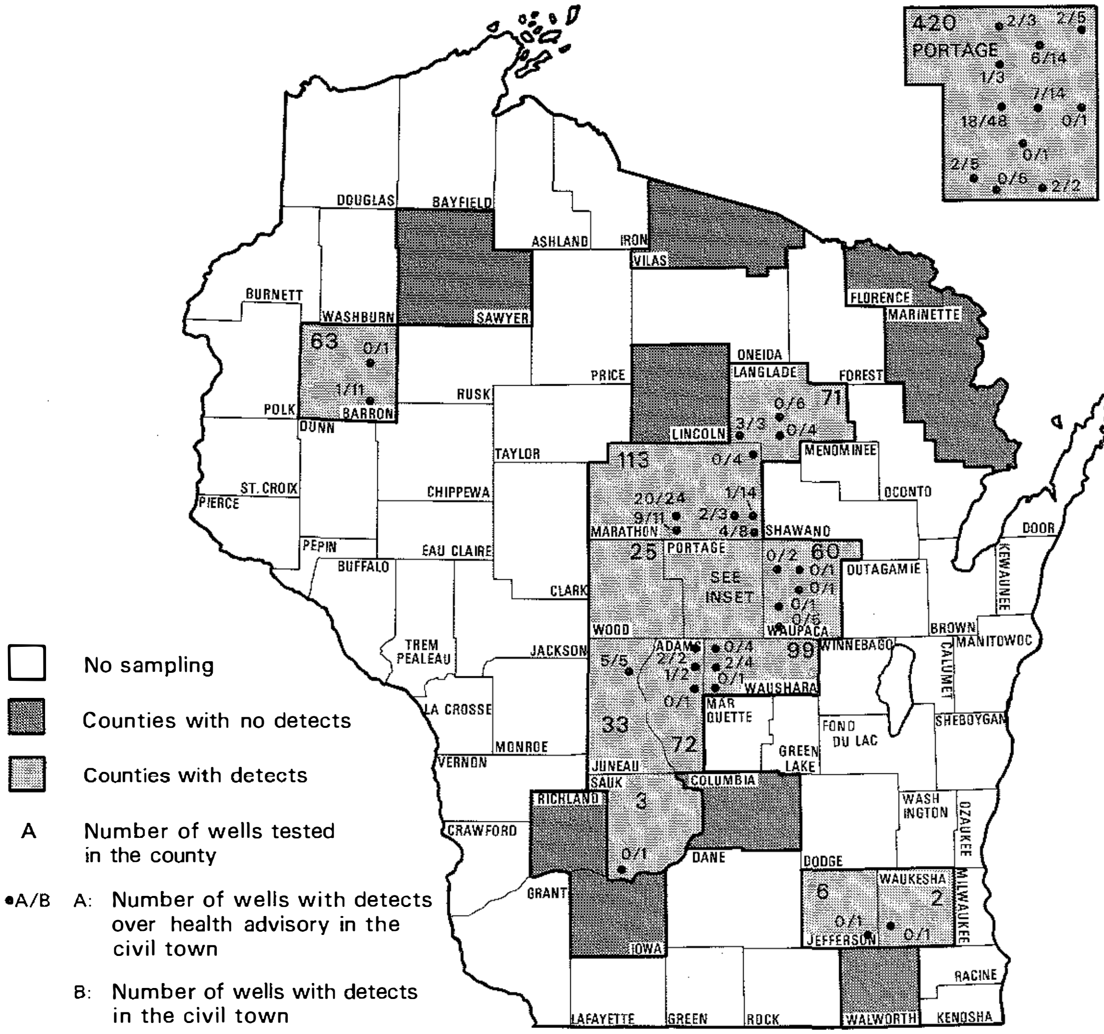


Figure A8. Aldicarb monitoring in Wisconsin (from Koth, 1985).

The organisms most commonly used as indicators of bacteriological contamination are the coliform bacteria. Current drinking-water standards require coliform bacteria to number less than one per 100 milliliters of a sample (Wis. Administrative Code, 1982). Coliform bacteria, which are harmless themselves, are used as indicators of the sanitary quality of groundwater. Their presence may indicate the presence of other more harmful fecal organisms or of pollution in its widest sense. However, a single sample with coliform bacteria does not necessarily mean that the water source itself is unsafe. Water can be contaminated through poor sampling technique or the distribution system may be contaminated. Repeated occurrences of bacteria in the groundwater are found in areas with limestone near the surface, such as Door County and northeastern Waukesha County.

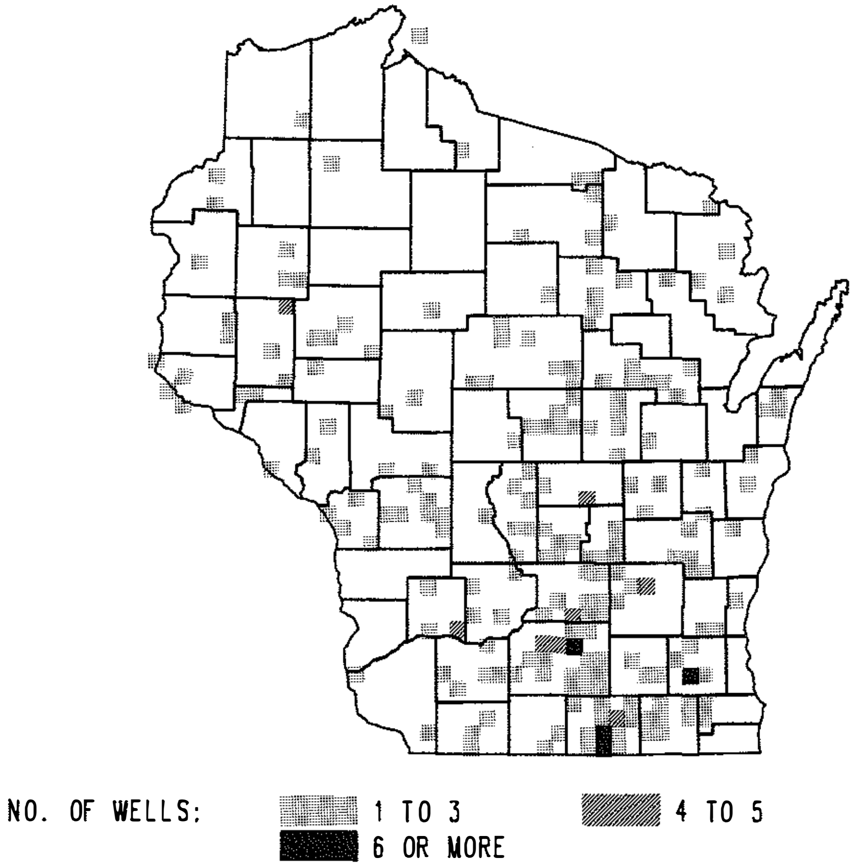


Figure A9. Noncommunity wells exceeding 10 mg/l nitrate-nitrogen (from Schreiber, 1986).

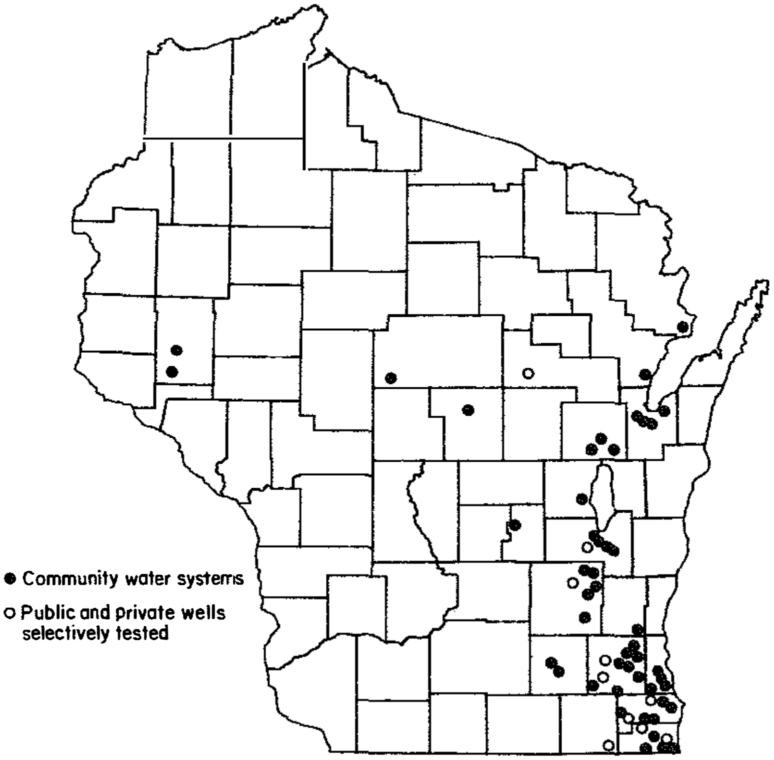


Figure A10. Wisconsin community water systems with radium violations (from Schreiber, 1986).

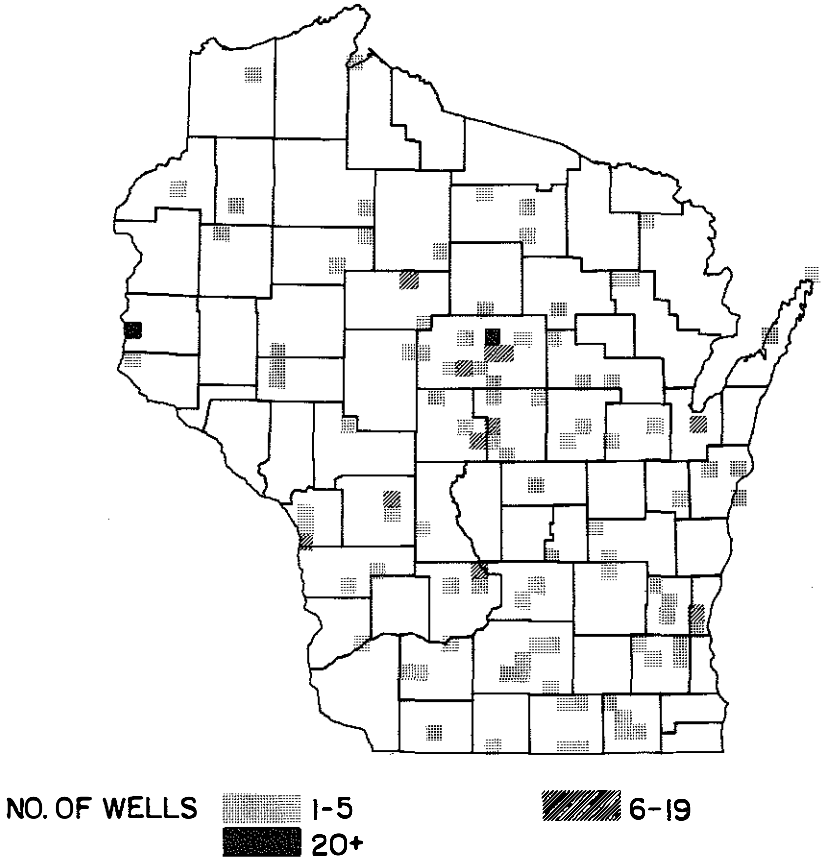


Figure A11. Number of wells exceeding Wisconsin groundwater quality standards for volatile organic chemicals (from Schreiber, 1986).

Appendix B. WISCONSIN WATER-QUALITY STANDARDS

CONTENTS

TABLES

Appendix B. WISCONSIN WATER-QUALITY STANDARDS

In Wisconsin there are two sets of numerical standards that apply to groundwater: drinking-water standards and groundwater quality standards. These standards are established for different reasons and purposes; and, as a result, the standards for an identical substance are not necessarily the same. However, there are similarities between drinking-water standards and groundwater standards. Both types of standards are set at a level necessary to protect public health. Groundwater standards have been set at the same level as the drinking-water standards if a drinking-water standard existed at the time the groundwater standard was established. This is because state law requires the groundwater standard to be identical to the federal standard if one exists. In many cases no federal standard has been established. In these cases, state law requires the groundwater standard to be established in accordance with a methodology established in chap. 160, Wis. Statutes.

Drinking-Water Standards

Current federal and state drinking-water regulations have established maximum levels for various constituents and properties of groundwater. They are based on potential health risks, possible physiological (laxative) effects, taste and odor or aesthetic and utility reasons. The drinking-water standards are promulgated by the U.S. Environmental Protection Agency (EPA) under the authority of the Safe Drinking Water Act of 1974. Wisconsin, which has delegation from EPA to run the Safe Drinking Water Program in the state, has adopted these standards in Chap. NR 109, Wis. Administrative Code (table B1). "Secondary Standards" in table B1 cover substances of aesthetic concern in public water systems. "Maximum Contaminant Levels" are the mandatory health-related standards. The standards are applicable to all public water systems in the state and apply whether the source of water is groundwater or surface water. For substances for which no drinking-water standards exist, the DNR has established health advisory limits after consultations with the Department of Health and Social Services.

There are no mandatory chemical drinking-water standards applicable to private wells. When a contaminant is found in a private well, the MCL for public water supplies is used as a guideline to judge the safety of the water. Where there is no MCL, a groundwater standard or health advisory limit may be used as the guideline for advising the well owner.

Water for Agriculture

Nondomestic water uses on farms include livestock consumption and irrigation. Water to be used by livestock is subject to quality limitations similar to those relating to drinking-water quality for human consumption. Most animals, however, are able to consume water considerably higher in dissolved-solids concentration than that considered satisfactory for humans. Table B2 lists concentration limits recommended by the U.S. Environmental Protection Agency (EPA) for water used by livestock (US EPA, 1973).

The chemical quality of water is an important factor to be considered in evaluating water for irrigation. The portion of the irrigation water consumed by plants or evaporated is essentially free from dissolved material. Growing plants selectively retain some nutrients and a portion of the mineral matter originally dissolved in the water; these retained substances, however, are not a large part of the total mineral concentration of irrigation water. The bulk of the dissolved solids originally present in the irrigation water remains behind in the soil. Salinity is not a problem in Wisconsin. Specific constituents in irrigation water can be undesirable; some may be damaging when present only in minute quantities. Recommended limits for undesirable constituents in irrigation water are given in table B2.

Table B1. Wisconsin drinking-water standards
(source, chap. NR 109, Wis. Administrative Code)

Constituent or property	Secondary standards	Maximum contaminant level (MCL)
Physical characteristics		
Color (color units)	15	
Odor (threshold no.)	3	
Turbidity (NTU)	1	5
Chemical characteristics		
Corrosivity	Noncorrosive	
Total dissolved solids (mg/l)	500	
Inorganic chemicals (all in milligrams per liter, mg/l)		
Chloride (Cl)	250	
Copper (Cu)	1.0	
Fluoride (F)	1.0 - 1.5	2.2
Iron (Fe)	0.3	
Manganese (Mn)	0.05	
Nitrate (as N)		10
Sulfate (SO_4)	250	
Zinc (Zn)	5	
Potential toxic substances:		
Arsenic (As)		0.05
Barium (Ba)		1.0
Cadmium (Cd)		0.01
Chromium (Cr)		0.05
Lead (Pb)		0.05
Mercury (Hg)		0.002
Selenium (Se)		0.01
Silver (Ag)		0.05
Dissolved gases:		
Hydrogen sulfide (H_2S)	Not detectable	
Organic chemicals (all in mg/l)		
Chlorinated hydrocarbons (pesticides):		
Endrin		0.0002
Lindane		0.004
Methoxychlor		0.1
Toxaphene		0.005
Chlorophonoxys (herbicides):		
2,4-D		0.1
2,4,5-TP silvex		0.01
Synthetic detergents (as MBAS)	0.5	
Trihalomethanes		0.1
Radioactivity and radionuclides (in picoCuries per liter, pCi/l)		
Gross alpha activity		15
Gross beta activity		50
Radium-226 and radium-228, combined		5
Strontium-90		8
Tritium		20,000
Microbiological contaminants		
Total coliform bacteria		< 1 per 100 ml

Table B2. Recommended concentration limits for water used by livestock and for irrigation crop production (source, U.S. EPA, 1973)

Constituent	Recommended limits (mg/l)	
	Livestock	Irrigated crops
Total dissolved solids	3,000	–
All crops	–	500
Sensitive crops	–	1,000
Tolerant crops	–	5,000
Aluminum (Al)	5	5
Arsenic (As)	0.2	0.1
Beryllium (Be)	no limit	–
Boron (B)	5	0.75
Cadmium (Cd)	0.05	0.01
Chromium (Cr)	1	0.1
Cobalt (Co)	1	0.05
Copper (Cu)	0.5	0.2
Fluoride (F)	2	1
Iron (Fe)	no limit	5
Lead (Pb)	0.1	5
Lithium (Li)	–	2.5
Magnesium (Mg)	no limit	–
Mercury (Hg)	0.01	–
Molybdenum (Mo)	no limit	–
Nickel (Ni)	–	0.2
Nitrate (as NO_3-N)	100	–
Nitrite (as NO_2-N)	10	–
pH	–	4.5–9.0
Selenium (Se)	0.05	0.02
Vanadium (V)	0.1	–
Zinc (Zn)	25	2
Pesticides	same as for drinking water	–

Groundwater Quality Standards

Many new regulations resulted from the enactment of the Wisconsin groundwater protection law, 1983 Wisconsin Act 410. Chap. 160, Wis. Statutes, created as part of this legislation, required DNR to adopt state groundwater quality standards to regulate sources of pollution. These numerical standards are to be based upon recommendations from the Wisconsin Department of Health and Social Services (DHSS) and apply to all regulated facilities, practices, and activities that may impact groundwater. All state agencies that regulate sources of groundwater pollution are required to comply with the groundwater standards. Under chap. 160, Wis. Statutes, DILHR, DATCP, DNR, DOT, and other state regulatory agencies must identify substances that have been or are likely to be detected in the groundwater and that result from activities regulated by those state agencies.

Chapter NR 140, Wis. Administrative Code, enacted to meet requirements of the law, establishes two levels of groundwater standards: an enforcement standard set at the maximum concentration of a substance allowable in groundwater and a preventive action limit (PAL) set at a percentage of the enforcement standard. "Enforcement standards" are levels of specific pollutants that cannot be legally exceeded. When an enforcement standard is exceeded, a state agency must enforce actions that will achieve compliance with the standard or prohibit continuation of the activity.

"Preventive action limits" (PALs) function as an early warning device to alert state agencies that low levels of pollution are developing and that some remedial action may be necessary to prevent pollution levels from increasing. PALs are also used to establish design and management criteria for some facilities and activities. Designing facilities (such as landfills) and carrying out activities (such as pesticide application) in ways that meet the PALs make it less likely that pollutant levels will reach the higher enforcement standards.

Standards have been established for 36 substances of health concern and 10 substances of welfare concern (substances that are usually not dangerous, but may present other problems such as unpleasant tastes or odors) (table B3). In addition, a methodology has been established for setting PALs for 15 indicator parameters (general indicators of groundwater quality) based on background groundwater quality. For all substances that have carcinogenic, mutagenic, or teratogenic properties or interactive effects, the preventive action limit is 10 percent of the enforcement standard. The preventive action limit is 20 percent of the enforcement standard for all other substances that are of public health concern. For each substance of public welfare concern, the preventive action limit is 50 percent of the enforcement standard.

Table B3. Wisconsin groundwater quality standards
(source, chap. NR 140, Wis. Administrative Code)

Substance	Enforcement standard	Preventive action limit (PAL)
	Public Health Groundwater Quality Standards (in micrograms per liter, except as noted)	
Aldicarb	10	2
Arsenic	50	5
Bacteria, total coliform	[Less than one in 100 ml for membrane filter method]	
Barium (mg/l)	1	0.2
Benzene	0.67	0.067
Cadmium	10	1
Carbofuran	50	10
Chromium	50	5
Cyanide	460	92
1,2-Dibromoethane	0.010	0.001
1,2-Dibromo-3-chloropropane (DBCP)	0.05	0.005
p-Dichlorobenzene	750	150
1,2-Dichloroethane	0.5	0.05
1,1-Dichloroethylene	0.24	0.024
2,4-Dichlorophenoxyacetic acid	100	20
Dinoseb	13	2.6
Endrin	0.2	0.02
Fluoride (mg/l)	2.2	0.44
Lead	50	5
Lindane	0.02	0.002
Mercury	2	0.2
Methoxychlor	100	20
Methylene Chloride	150	15
Nitrate + Nitrite (as N)(mg/l)	10	2
Selenium	10	1
Silver	50	10
Simazine (mg/l)	2.15	0.43
Tetrachloroethylene (PCE)	1	0.1
Toluene	343	68.6
Toxaphene	0.0007	0.00007
1,1,1-Trichloroethane	200	40
1,1,2-Trichloroethane	0.6	0.06
Trichloroethylene (TCE)	1.8	0.18
2,4,5-Trichlorophenoxypropionic acid	10	2
Vinyl chloride	0.015	0.0015
Xylene	620	124
	Public Welfare Groundwater Quality Standards (in milligrams per liter, except as noted)	
Chloride	250	125
Color (color units)	15	7.5
Copper	1.0	0.5
Foaming agents (MBAS)	0.5	0.25
Iron	0.3	0.15
Manganese	0.05	0.025
Odor (threshold odor no.)	3	1.5
Sulfate	250	125
Total dissolved solids (TDS)	500	250
Zinc	5	2.5

Appendix C. WISCONSIN AGENCIES PROVIDING INFORMATION AND TECHNICAL ASSISTANCE

AGENCY	LOCATION	PHONE NUMBER
Department of Agriculture, Trade and Consumer Protection (DATCP)	Check the local telephone directory, or contact: Agricultural Resource Management Division 801 W. Badger Rd. Madison, WI 53708	(608) 266-2295
Department of Health and Social Service (DHSS)	Check the local telephone directory, or contact: Environmental Health Bureau 1414 E. Washington Ave. Madison, WI 53702	(608) 266-1704
Department of Industry, Labor and Human Relations (DILHR)	201 E. Washington Ave. Madison, WI 53703	(608) 266-3131
Department of Natural Resources (DNR):	101 S. Webster Madison, WI 53702	(608) 266-2621
Division of Environmental Standards	101 S. Webster Madison, WI 53702	(608) 266-2621
District Offices:		
Southern District	3911 Fish Hatchery Road Madison, WI 53711	(608) 275-3266
Southeast District	Box 13248 9722 Watertown Plank Rd. Milwaukee, WI 53213	(414) 562-9500
Lake Michigan District	Box 3600 1125 N. Military Ave. Green Bay, WI 54303	(414) 497-4040
North Central District	Box 818 Rhinelander, WI 54501	(715) 362-7616
West Central District	1300 W. Clairemont Ave. Call Box 4001 Eau Claire, WI 54701	(715) 839-3700
Northwest District	Highway 70, Box 309 Spooner, WI 54801	(715) 635-2101
State Laboratory of Hygiene	465 Henry Mall Madison, WI 53706	(608) 262-1293
USDA, Soil Conservation Service (SCS)	Check the local telephone directory, or contact: 4601 Hammersley Rd. Madison, WI 53711	(608) 264-5341

Appendix C. (continued)

AGENCY	LOCATION	PHONE NUMBER
U.S. Geological Survey (USGS), Water Resources Division, Wisconsin District	6417 Normandy Lane Madison, WI 53719	(608) 274-3535
University of Wisconsin Cooperative Extension:		
UWEX County Offices	Check the local or regional telephone directory	
Central Wisconsin Groundwater Center	010 Student Services Center UW - Stevens Point Stevens Point, WI 54481	(715) 346-4270
Wisconsin Geological and Natural History Survey (WGNHS)	3817 Mineral Point Road Madison, WI 53705	(608) 262-1705
County Governments or Regional Planning Commissions	Check the local or regional telephone directory	

GLOSSARY

Many words used in this document are technical in nature. This glossary defines the most unfamiliar words used. Some of the terms are also defined the first time they appear in the text.

Adsorption -- Adherence of ions in solution to the surface of solids.
Alluvial deposits -- The materials laid down in river channels or on floodplains.
Animal unit -- One animal unit equals 1,000 lbs animal weight equivalent.
Aquifer -- A saturated permeable geologic formation that contains and will yield significant quantities of water.
Artesian pressure -- The pressure exerted by the water in a confined aquifer that will raise the well-water level above the top of the aquifer.
Attenuate (pollution) -- To reduce the severity of pollution; to lessen the amount of pollutants.

Bedrock -- Solid rock overlain by unconsolidated material.

Cone of depression -- The cone-shaped area around a well in which the water level has been lowered by pumping.
Contamination -- Introduction of objectionable material into water that may cause adverse health effects.

Dolomite -- A limestone rich in magnesium carbonate minerals.
Drawdown -- The lowering of groundwater level caused by pumping a well.

Fluvial -- Produced by river action.

Loess -- Silt-sized material deposited by the wind.

Outwash -- Sorted sandy sediment deposited by meltwater streams beyond active glacier ice.

Paleozoic -- An era of geologic history beginning approximately 600 million years ago. In Wisconsin, it comprises Cambrian, Ordovician, Silurian, and Devonian systems.
Permeability -- The ability of a rock or soil to transmit water.
Pesticide -- Any material used to control, mitigate, or destroy pests, such as insecticide, herbicide, fungicide, bacteriacide, or rodenticide.
pH -- A measure of acidity and alkalinity of water on a scale from 0 to 14; with 7 representing neutrality, numbers less than 7 increasing acidity, and numbers greater than 7 increasing alkalinity.
Pleistocene -- The earlier of the two most recent geologic epochs, in which glacial activity was very frequent (for this reason also called glacial epoch); about 10,000 to 1 million years ago.
Pollution -- Introduction of undesirable substances (pollutants), by natural processes or human actions, leading to alteration or degradation of natural conditions.
Precambrian -- The earliest time unit of geologic time; older than 600 million years.
Precipitation -- Water in the form of rain, hail, sleet, or snow.

Quaternary -- The most recent geologic era beginning approximately 1 million years ago, including the Pleistocene and Recent epochs.

Soil -- The top 5 feet or less of materials at the land surface.
Soil solum -- Layer of soil above the parent material that includes the A and B horizons.

Till -- Unsorted sediment deposited by a glacier (incorrectly called drift).

Unconsolidated deposits -- Loose material overlying bedrock. Includes soil, glacial deposits, stream sediment, windblown deposits, weathered bedrock, and organic deposits.

Water table -- The upper surface of the saturated zone (appears as the level at which water stands in a well penetrating the unconfined aquifer).

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