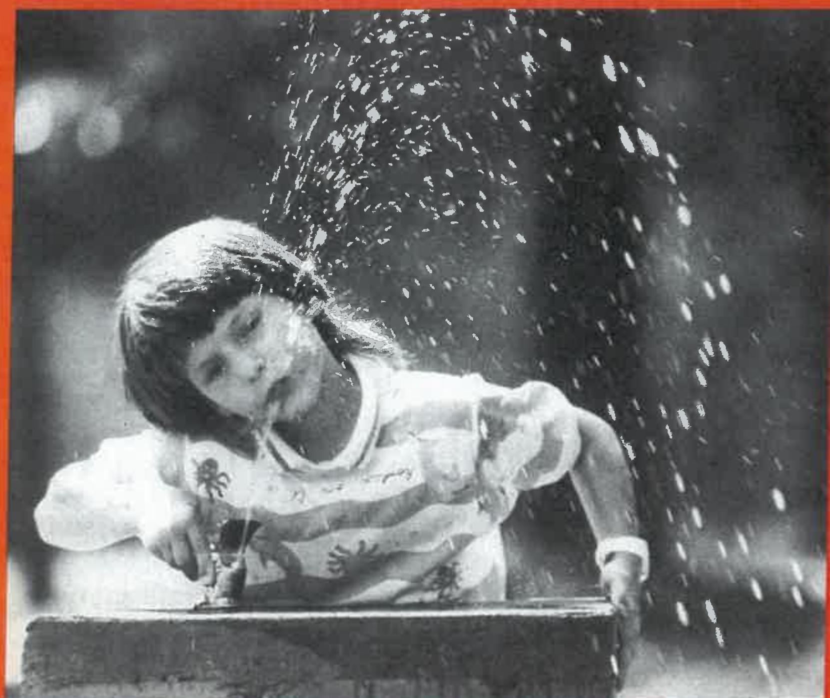


A Guidebook to

GROUNDWATER

Resources & Education Opportunities in the Great Lakes Region

Great Lakes Commission

CONTENTS

PREFACE

Given the pervasive influence of Great Lakes resources on the economy, environment and quality of life of the citizens of eight states and two Canadian provinces, one might assume that related educational materials would have an equally pervasive presence in the K-12 classroom curriculum and non-formal education settings. In reality, however, this is not the case. In 1988 and 1989 a study by the Great Lakes Commission found that both classroom and non-formal education on Great Lakes issues is limited in scope, largely undocumented and varying greatly in focus and depth. A concern has also been expressed that a well-defined Great Lakes education network does not exist, a situation that inhibits information exchange and compromises the potential for the development and use of surface and groundwater education materials.

Beginning in the fall of 1990, the Commission, with support from the W.K. Kellogg Foundation of Battle Creek, Michigan, began a two-year initiative to promote the informed use, management and protection of the groundwater resources of the Great Lakes region through the development and promotion of a regionwide groundwater education strategy and through an aggressive information dissemination campaign to educate the Great Lakes region's citizens about the importance of groundwater.

In late 1990, the Commission created a Groundwater Education Task Force comprised of groundwater educators and technical experts from the eight Great Lakes states, Ontario and numerous federal and regional agencies (see Appendix D for the complete listing of members).

The three principal charges undertaken by the Task Force included:

1. Production of a groundwater education guidebook for the Great Lakes region —

- *describing the physical aspects of the groundwater resource in the region;*
- *defining its economic and environmental importance to citizens;*
- *exploring current management programs and priorities; and*
- *introducing readers to a wealth of available resources including curriculum materials.*

This guidebook addresses the first charge and is the culmination of a two-year long effort of the Groundwater Education Task Force.

2. Planning and convening a series of groundwater education roundtables and a regional summit meeting for leading educators and policy officials in various locations throughout the Great Lakes region.

More than 375 participants attended the five roundtables held between June 1991 and March of 1992, with nearly 200 attending the Summit meeting on May 11-12, 1992 in Chicago. The following schedule presents the individual dates of the meetings:

DATE	MEETING, LOCATION
June 20, 1991	Michigan Roundtable East Lansing, MI
October 2, 1991	Minnesota/Wisconsin Roundtable Wayzata, MN
November 15, 1991	Illinois/Indiana Roundtable Champaign, IL
December 6, 1991	Ohio Roundtable Columbus, OH
March 12, 1992	New York/ Ontario/ Pennsylvania Roundtable Buffalo, NY
May 11-12, 1992	Groundwater Education Summit Chicago, IL

3. Preparation of a regional groundwater education strategy, reflecting the findings and recommendations from the five roundtables and summit meeting, to serve as a framework to promote groundwater education programs in the Great Lakes region.

The strategy was prepared by the Task Force and presented to the Great Lakes Commission for approval at its 1993 Semi-Annual Meeting in Montreal, Quebec.

Appreciation is extended to all members of the Task Force, (See Appendix D) and to the individuals who participated in the Commission-sponsored education roundtables and summit meeting.

Project design, conduct and oversight was provided by Dr. Michael J. Donahue, Executive Director, Great Lakes Commission.

Project management was provided by Thomas Crane, Program Manager, Resource Management and Environmental Quality, with assistance from Martha Reesman, Program Manager, Special Projects (through June 1992).

The principal author of this guidebook is Paul A. Feder, Research Associate (currently with U.S. EPA Region IX, San Francisco, California).

Carol Ratza, Program Manager, Communications, edited the guidebook and Rita Straith, Administrative Assistant, provided production assistance.

Others contributing to the preparation and printing of this guidebook include Dillard and Marie Murrell (design and production), Karen Cogsdill (cover design) and more than seventy participants from the five education roundtables who reviewed and critiqued this guidebook. Special thanks are extended to the staff of the Groundwater Education in Michigan (GEM) project of the Institute for Water Research at Michigan State University, particularly Linda Helstowski and Carol Misseldine.

Preparation and production of this document was made possible through a grant from the W.K. Kellogg Foundation of Battle Creek, Michigan.

All measures, units and monetary values presented in this guidebook are in U.S. figures unless otherwise specified.

known as geology, gives rise to the relatively new and very exciting field of hydrogeology. Hydrogeologists are geologists who specialize in the study of groundwater. They investigate the movement of water and contaminants through aquifers. They also investigate and characterize the physical and hydrologic characteristics of aquifers and the long term yield of aquifers and groundwater basins. An **aquifer** is a soil or rock formation containing sufficient groundwater to supply water to wells and springs.

5. What are the important characteristics of a groundwater aquifer?

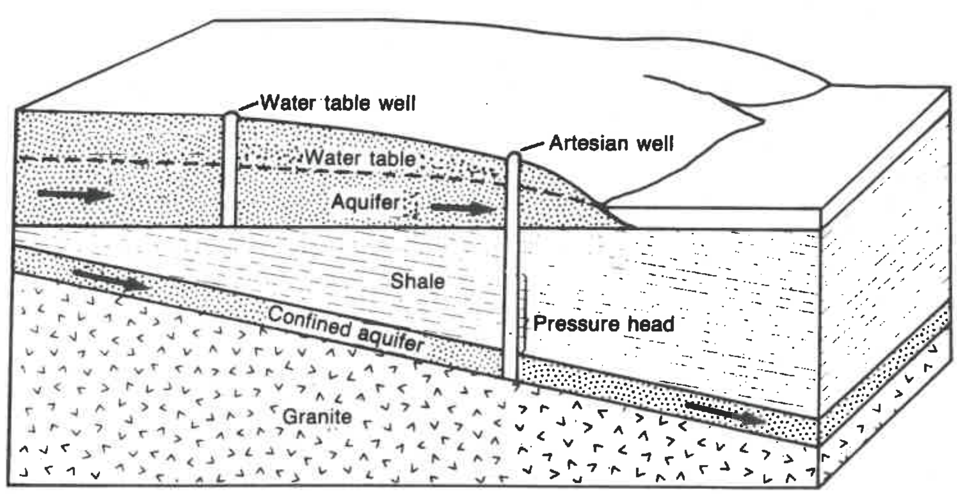
Aquifer characteristics are as variable as the materials that make them up. Aquifers may be made of solid bedrock, soil, or, as is common in the Great Lakes region, consist of unconsolidated or loosely held together materials such as clay, sand, and gravel. One of the most important aquifer characteristics, **permeability**, is a measure of how easily water flows through the aquifer. Permeability is controlled by the amount of open or pore space (porosity) within the soil or rock and how interconnected the pores are. Since very fine materials such as clay or silt have very low porosity, water does not readily pass through them and they are considered virtually **impermeable**. A highly impermeable geologic layer that will not transmit water is called an **aquitard**. With the exception of sandstone, bedrock aquifers do not generally yield a substantial amount of water unless they have large interconnected openings or cracks.

Two major types of aquifers are confined and unconfined aquifers (see Figure 1-2). When an aquifer is restricted, under pressure from overlying, impermeable soil or rock, it is known as a **confined or artesian aquifer**. When a well is drilled through a confined aquifer, the water pressure in the aquifer forces the water level to stand above the level of the aquifer itself (see diagram). **Unconfined aquifers** are not under pressure, thus the water level in a well is the same as that of the water in the surrounding aquifer.

6. How fast does groundwater flow?

Groundwater generally moves very slowly. Groundwater flow is commonly measured in terms of feet per day. However, depending on an aquifer's permeability, groundwater flow rates may be much faster (feet, yards, sometimes or even miles per day), or slower (inches per day or less). While groundwater may move very quickly through coarse

Figure 1-2
Unconfined (water table) and confined (artesian) aquifers



Source: U. S. Geological Service

Introduction

HOW TO USE THIS GUIDEBOOK

This guidebook identifies groundwater resource tools and information available to educators, public officials, agency representatives, and communities in the Great Lakes region. Its basic premise is that comprehensive protection of groundwater resources, of critical importance to everyone in the Great Lakes region, depends on the initiative of local protection efforts and an educated citizenry.

This guidebook is a unique resource document, presented in a question and answer format, to 1) provide a regionwide perspective on groundwater issues and 2) publicize the availability and promote the use of our region's protection programs and educational resources.

This guidebook also addresses the importance of integrating groundwater curricula into our schools; it will be of value to K-12 classroom educators primarily as a resource document. It does not provide classroom-ready materials for use by teachers, but does direct teachers to such materials.

This guidebook includes eight chapters plus appendices. **Chapter 1** presents basic information about groundwater, what it is, where it comes from, and the role that it plays in the hydrologic cycle. Many of the concepts introduced in this chapter are expanded upon in later chapters discussing groundwater protection programs, activities, and education opportunities.

Chapter 2 is an overview of groundwater resources in the Great Lakes region, providing information about the occurrence of groundwater, how it interacts with the natural environment, and groundwater usage classified by user-group categories.

Chapter 3 summarizes groundwater contamination issues and answers key questions about groundwater quality as well as presenting information about contamination sources and prevention.

Chapter 4 outlines federal, regional, state, provincial and local groundwater protection programs. It is intended for use as a reference for individuals interested in the most pertinent groundwater protection programs in their area.

Chapter 5 describes groundwater education opportunities in the Great Lakes region for classroom teachers, local officials, business and industry leaders, the agricultural community and the general public.

Chapter 6 addresses the critically important role of citizen and community involvement in groundwater protection and answers critical questions about what individuals and communities can do in "their own backyards" to help protect and conserve groundwater.

Chapter 7 lists available resources and reference materials by state/province, federal agency and other sources for readers interested in obtaining groundwater education curricula and other important resources.

Chapter 8 is a bibliography of available resources and literature.

Finally, the accompanying appendices provide important supplemental information for readers, particularly those working in an education-related field.

Appendix A provides background on the Great Lakes Commission's Groundwater Education Initiative and synthesizes the findings and recommendations from five groundwater education roundtables convened throughout the Great Lakes region from June 1991 through March 1992.

Appendix B is a glossary of groundwater terms and concepts that are used throughout this guidebook.

Appendix C is a unit measure conversion table.

A list of all Groundwater Education Task Force Members is provided in **Appendix D.**

Chapter 1

GROUNDWATER BASICS

Groundwater plays a critical role in the social, ecological, and economic well being of the Great Lakes region. Some 45 million of the region's residents depend on groundwater for all or part of their drinking water supply. Communities of all sizes, as well as private residences, business and industry withdraw more than one billion gallons of groundwater each day to meet their fresh water needs. Groundwater is one of the Great Lakes region's most precious natural resources.

Despite groundwater's fundamental importance to the Great Lakes region's economic and environmental vitality, the basics of understanding groundwater remain clouded by a great number of myths and misunderstandings.

Groundwater has historically (though mistakenly) been regarded as a resource of secondary importance. It has been viewed as a seemingly endless and high quality resource, relatively free from damage and depletion. Furthermore, the historical failure to recognize groundwater resources as part of the Basin's single hydrologic or water system has contributed to the creation of a fragmented system of groundwater laws and protection programs. The effects of urban and rural development on groundwater have been worsened by limited knowledge and understanding of groundwater flow and the interrelationship of surface and groundwater.

This chapter provides a brief introduction to groundwater. It is designed to dispell some common groundwater myths and give the reader the critical understanding necessary for active learning and participation in groundwater issues. To begin, the reader will discover what groundwater is, where it comes from, and how it interacts with rivers and lakes.

This chapter also provides an introduction to some important groundwater terms and the science of groundwater. A *Glossary of Groundwater Terms* is provided in Appendix B. Many of the concepts introduced here will be revisited in later chapters addressing specific groundwater protection issues and opportunities.

A. GROUNDWATER AND THE HYDROLOGIC CYCLE

1. What is groundwater and where does it come from?

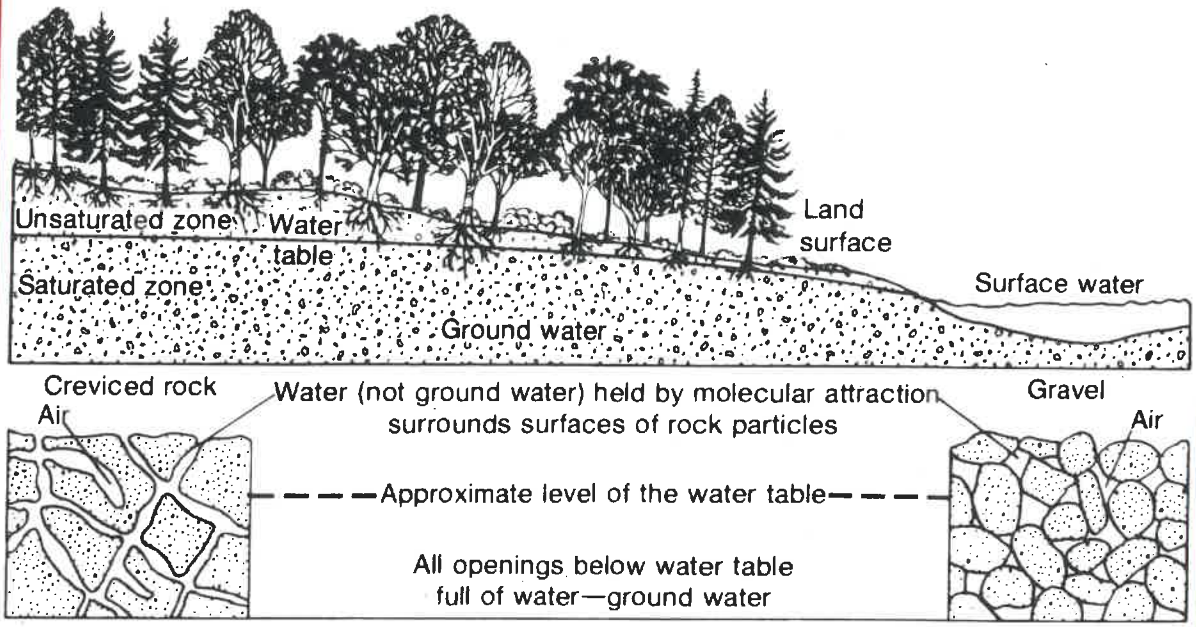
Like water in a sponge, groundwater is water held in the ground. Contrary to common belief, groundwater does not generally occur in underground rivers, lakes, or reservoirs. Groundwater is generally held in open spaces, called pores, within soil and rock (see Figure 1-1).

Groundwater is an integral part of the **hydrologic cycle** — the constant cycling of water through the landscape into the atmosphere and back again to the land. Thus, groundwater begins when rain or snow falls to the earth and soaks or **infiltrates** through the ground downward to the water table. The **water table** is the highest level of the groundwater and thus marks the level below which all interconnected spaces in soil and rock are completely filled or **saturated** with water. The remaining rainfall or snowmelt flows as **runoff** over the ground surface into streams, rivers, lakes, and the oceans or returns to the atmosphere by evaporation.

2. How are groundwater and surface water connected?

An integral part of the hydrologic cycle, groundwater acts as a reservoir for storing and transmitting water and thus directly affects both the quantity and quality of surface water resources. Constantly on the move, groundwater flow originates in areas where infiltration of precipitation or streamflow occur and flows from areas of higher elevation to areas of lower elevation (known as **recharge areas**), and ends where it leaves the ground as discharge. Groundwater discharges wherever the water table intersects the ground surface. Groundwater discharge is often essential for maintaining surface waters and is particularly critical in dry periods when wetlands, streams, and rivers depend

Figure 1-1
How groundwater occurs in rocks



Source: U. S. Geological Service

on it for all or most of their water. The portion of water that originates as groundwater discharge is known as the **base flow** of a stream or river.

3. Why does groundwater need to be protected?

Groundwater is a very precious resource for everyone in the Great Lakes region. Approximately 45 million people depend on groundwater for all or part of their drinking water supply. More than one billion gallons of groundwater are withdrawn daily to provide an essential source of fresh water to communities, private residences, business and industry in the region.

Groundwater is very vulnerable to contamination from any activity that involves hazardous substances. Groundwater is at risk, not just by large industrial polluters, but by municipal landfills, farms, gasoline service stations, dry cleaners, and private septic systems. The economic impacts of groundwater contamination are staggering. Major examples include residential and comercial property devaluation, lack of business development, as well as the costs associated with long-range operation and maintenance of water treatment facilities, alternative water supply development, cleanup, and liability.

Cleaning contaminated groundwater is very difficult and expensive. Once contaminated, groundwater may remain that way for hundreds of years. The only practical response is to protect groundwater before it becomes contaminated. The economic, social, and environmental importance of groundwater in the Great Lakes region makes groundwater protection a priority for everyone!

B. GROUNDWATER HYDROLOGY AND GEOLOGY

4. What is hydrogeology?

The study of the dynamics, movement, and occurrence of groundwater, known as groundwater hydrology, when combined with the study of the earth's materials, known as geology, gives rise to the relatively new and very exciting field of hydrogeology. Hydrogeologists are geologists who specialize in the study of groundwater. They investigate the movement of water and contaminants through aquifers. They also investigate and characterize the physical and hydrologic characteristics of aquifers and the long term yield of aquifers and groundwater basins. An **aquifer** is a soil or rock formation containing sufficient groundwater to supply water to wells and springs.

5. What are the important characteristics of a groundwater aquifer?

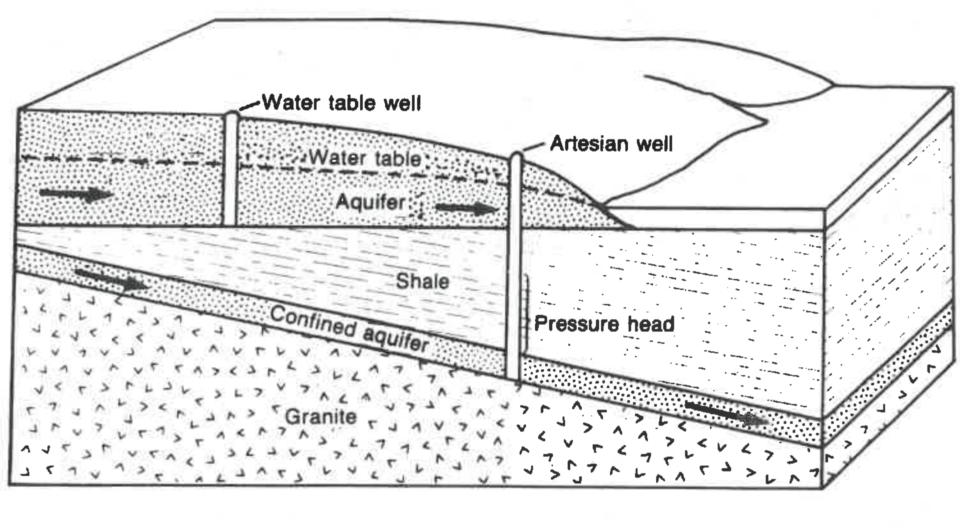
Aquifer characteristics are as variable as the materials that make them up. Aquifers may be made of solid bedrock, soil, or, as is common in the Great Lakes region, consist of unconsolidated or loosely held together materials such as clay, sand, and gravel. One of the most important aquifer characteristics, **permeability**, is a measure of how easily water flows through the aquifer. Permeability is controlled by the amount of open or pore space (porosity) within the soil or rock and how interconnected the pores are. Since very fine materials such as clay or silt have very low porosity, water does not readily pass through them and they are considered virtually **impermeable**. A highly impermeable geologic layer that will not transmit water is called an **aquitard**. With the exception of sandstone, bedrock aquifers do not generally yield a substantial amount of water unless they have large interconnected openings or cracks.

Two major types of aquifers are confined and unconfined aquifers (see Figure 1-2). When an aquifer is restricted, under pressure from overlying, impermeable soil or rock, it is known as a **confined or artesian aquifer**. When a well is drilled through a confined aquifer, the water pressure in the aquifer forces the water level to stand above the level of the aquifer itself (see diagram). **Unconfined aquifers** are not under pressure, thus the water level in a well is the same as that of the water in the surrounding aquifer.

6. How fast does groundwater flow?

Groundwater generally moves very slowly. Groundwater flow is commonly measured in terms of feet per day. However, depending on an aquifer's permeability, groundwater flow rates may be much faster (feet, yards, sometimes or even miles per day), or slower (inches per day or less). While groundwater may move very quickly through coarse

Figure 1-2
Unconfined (water table) and confined (artesian) aquifers



Source: U. S. Geological Service

gravel, fractured limestone, or loose soil, it moves much more slowly through less permeable, generally finer, aquifer materials.

The distance between an aquifer's recharge area and where it discharges may be very localized, covering tens of meters in days or weeks, or it may be a deeper, regional system, covering many kilometers in years, decades, or centuries. While there is great variability in the speed and nature of groundwater flow, its movement is generally predictable: it typically moves in parallel layers or paths from higher elevation recharge areas to discharge points at lower elevations.

7. How do scientists study the characteristics and conditions of aquifers?

Scientists use a variety of laboratory and field methods to study the characteristics and condition of an aquifer. Some of these techniques are performed on the surface and some are performed from the subsurface using exploratory borings or wells.

Using information on the soils, topography, stream flow, surface geology, and from aerial photo interpretation, hydrogeologists can derive significant understanding of an area's groundwater system. By drilling exploratory borings, collecting and analyzing soil or rock boring samples, and installing wells, hydrogeologists can gain even more information, helping to confirm or deny their previous understanding. Geophysical methods, specialized techniques which use sound waves and electrical currents to interpret subsurface conditions, are another valuable tool for studying groundwater.

Regardless of the methods used, however, groundwater cannot be seen and therefore it is impossible to acquire a complete picture of a groundwater system. Instead, investigators must piece together the groundwater puzzle using every piece of available information to infer and predict as much as possible about the subsurface conditions.

Chapter 2

GROUNDWATER IN THE GREAT LAKES REGION

Before we begin our discussion of groundwater and its interaction with the surface waters of the Great Lakes, it is necessary to distinguish between the Great Lakes region as a whole, and the unique ecosystem existing in the drainage basin of the Great Lakes.

The Great Lakes Basin ecosystem, as defined by the U.S./Canada *Great Lakes Water Quality Agreement of 1978*, means the "interacting components of air, land, water and living organisms, including humans, within the drainage basin of the St. Lawrence River at or upstream from the point at which this river becomes the international boundary between Canada and the United States," Parts of eight states (Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, and Wisconsin) and two provinces (Ontario and Quebec) are within the binational Great Lakes Basin's boundaries (drainage area). Figure 2-1 shows the exact area encompassed by the Great Lakes Basin.

In general, a broader definition, not limited by hydrologic boundaries, is meant when we refer to the Great Lakes region. It is useful to consider the region as a whole, rather than the Basin, because while the actual land area in the Basin is small compared to the area of the Great Lakes, that land area is vitally important to the economic and environmental well being of a large part of North America. The Great Lakes region means different things to different people, but for purposes of this publication, when we refer to the Great Lakes region we will be considering, inclusively, the jurisdiction of the eight Great Lakes states and the Province of Ontario.

Groundwater affects each and every resident in the Great Lakes region. This chapter highlights groundwater's role in supporting the region's ecological and economic systems.

The first section is an overview of groundwater's role in the Great Lakes Basin ecosystem; providing information about groundwater's natural occurrence, how it interacts with the physical environment and the Basin's abundant plant and animal life.

The second section is an overview of groundwater usage. It begins with a discussion of groundwater's importance to regional and local economies and how groundwater contamination can threaten a community's economic vitality. This is illustrated with case studies of groundwater contamination. The chapter ends with a discussion of groundwater usage presented by user-sectors including: domestic; public/municipal; industrial; agricultural; and oil and gas development.

A. GROUNDWATER AND THE GREAT LAKES BASIN ECOSYSTEM

While groundwater is increasingly valued for its tremendous beneficial uses to society, groundwater is also essential for sustaining the Great Lake Basin's ecosystem. Groundwater is an integral part of the landscape; helping to maintain water movement through the hydrologic cycle as well as the health of plant and animal communities.

1. What is unique about the hydrology and geology of the Great Lakes Basin?

The Great Lakes, containing twenty percent of the world's fresh surface water supply, is the world's largest continuous body of freshwater. The Basin is a single hydrologic unit, and since global weather patterns carry moist air in and out of the Basin it is also part of the global hydrologic cycle.

A unique characteristic of the Great Lakes Basin is that almost one-third of its area is covered by surface water. Unlike most large water basins, there are no dominant river or tributary systems. Instead, more than a dozen large tributary river basins each drain approximately 6,000 square miles of land.

Figure 2-1
Water and related land resources in the Great Lakes Basin form a single, interconnected ecosystem

Source: Great Lakes Commission

Igneous and metamorphic rocks form the underlying geologic structure of the Great Lakes Basin. These so called "basement rocks" were deposited between 600 million and 3 billion years ago in the Precambrian era (see Table 2-1). These rocks are exposed in the northern and northwestern portion of the Basin and extend southward where they are covered by a sequence of sedimentary rocks. These sedimentary or water-deposited rocks were left by marine seas which covered much of the continent during the Paleozoic Era between 230 and 600 million years ago. See Figure 2-2 showing bedrock in the Great Lakes Basin.

During the most recent geologic period, the pleistocene, four major glacial advances radically transformed the topography (surface elevations and landforms) and ecosystem of the area. These enormous 'continental' glaciers, with a thickness of up to 2,000 meters (6,500 feet), advanced from the north carving out the five Great Lakes and leaving huge quantities of glacial debris. These unconsolidated (or loosely held together) glacial deposits, with a depth to bedrock of up to 305 meters (1000 feet), are now the dominant surface material in the Basin. The varied topography of the southern Basin with hundreds of thousands of marshes, bogs, ponds and lakes, is characteristic of a glacially-formed landscape.

Table 2-1
Geologic history of the Great Lakes Basin
(years before present)

Geologic Period	Geologic Events
Pleistocene Epoch (13 million yrs – present)	Repeated advance/retreat of continental glaciers-formation of current Great Lakes
Cenozoic Era (13 – 63 million)	Relative geologic inactivity
Mesozoic Era (63 – 230 million)	Gradual decline of marine seas – continued deposition of sedimentary and carbonate rock layers
Paleozoic Era (230 – 600 million)	Marine seas cover much of North America – formation of limestones, shales, sandstones, halite (salt), and gypsum
Precambrian Era (600 million – 3+ billion)	Formation of Canadian Shield, metamorphic and crystalline basement rocks

2. Where is groundwater located in the Great Lakes Basin?

Groundwater is present everywhere in the Basin and is very abundant. Groundwater occurs both in unconsolidated, glacial sediments and in the bedrock. These aquifers vary considerably in their water-holding capacity.

Collectively known as 'glacial drift', these glacial deposits are composed of clay, silt, sand, gravel, and boulders. In some areas the action of glacial-fed streams sorted anc the action of glacial-fed streams sorted anc redeposited the glacial drift in deposits o uniform sediment size. This is the origin o the sand and gravel deposits which ar productive aquifers, supplying some well with as much 2,500 gallons per minute Throughout the Basin, these highly produ tive aquifers can be found along man present day streams. When deposited a "unsorted" mixtures of clay, silt, sanc gravel and boulders together, the glaci sediments are generally poor aquifers.

The Basin's bedrock aquifers are mo productive where they are covered by pe meable, surface materials that act as a cha nel conveying water or recharge from tl surface. Water is held in the bedrock's pe meable zones, which include fractures, or carbonate/limestone formations, in crac that are created by water dissolving the ro Sandstone bedrock forms excellent aquif in upper Michigan, Illinois, Minnesota, W consin, and New York.

3. What is the quality of groundwater in the Great Lakes Basin?

The quality of groundwater in the Gr Lakes Basin varies from very pure to seve contaminated. Groundwater quality is fected by both human activities and nat processes. However, serious degradatio groundwater is generally associated w human-caused contamination. While m

Basin residents can drink groundwater directly from their well, others must first soften or purify it to take out naturally occurring minerals. As groundwater passes through the ground it can become "mineralized" or enriched with minerals. In general, highly mineralized water occurs in deep aquifers throughout the Basin. Groundwater contamination from human activities is a major concern throughout the Great Lakes Basin. Chapter 3 discusses groundwater contaminants from both human and natural sources.

4. Are all aquifers in the Basin vulnerable to groundwater contamination?

Yes, all aquifers are vulnerable to groundwater contamination and must be protected. Since most groundwater contamination originates at the ground surface, the most vulnerable aquifers are those shallow aquifers which lie beneath a thin, highly permeable surface material or recharge area. Chapter 3 discusses the geologic factors which determine an aquifer's vulnerability.

Critical examples of this are shallow sand and gravel aquifers and limestone and dolomite aquifers. Where limestone and dolomite aquifers are protected by only a thin covering of surface material, they are the most susceptible to contamination. Contaminants move quickly through these aquifers because of their open and highly permeable structure of channels and cavities that form by dissolution in water.

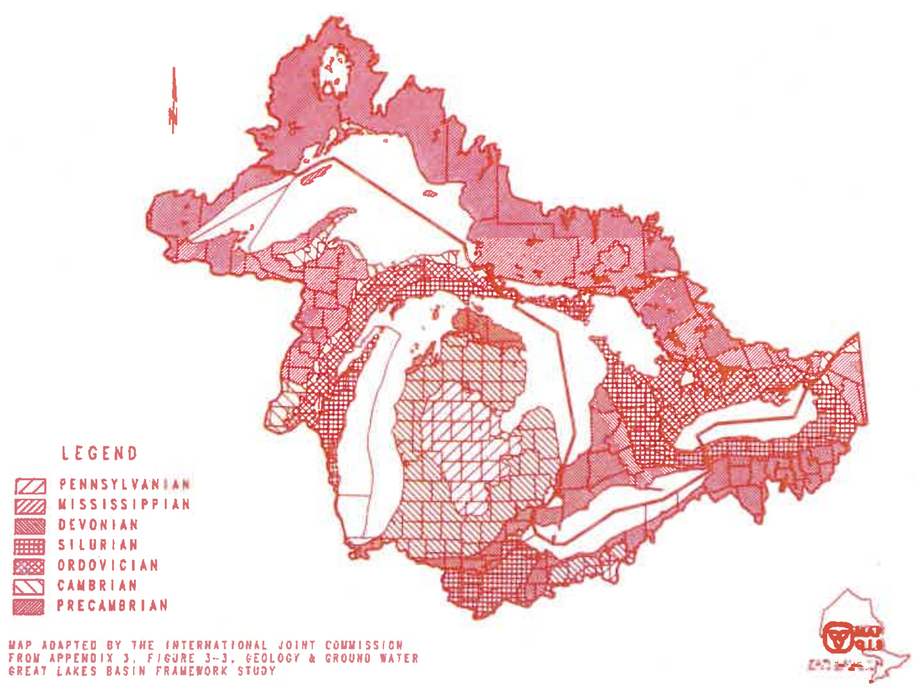
5. Do the individual lake basins have distinct groundwater resources?

While it is possible to make general distinctions between the groundwater resources of each of the five Great Lakes, many of the same aquifer characteristics and groundwater protection concerns exist throughout the Basin. More important to appreciate is the high level of variability and inconsistency that characterize much of Basin's groundwater. Even within very localized areas it is not uncommon to have great variability in an aquifer's characteristics such as water quality, volume, and permeability.

6. What role does groundwater play in the hydrologic system of the Great Lakes?

As highlighted in Chapter 1, groundwater is a critical element of the hydrologic cycle (maintaining drainage, storing and transmit-

Figure 2-2
Bedrock geology of the Great Lakes



Source: GIS Unit, Resource Management Branch, Ontario Ministry of Agriculture and Food ting water, and directly influencing both the quantity and quality of surface water resources). Abounding in surface water, the Great Lakes region too often overlooks the fact that groundwater is an integral component of the hydrologic cycle.

Groundwater enters the Lakes directly via natural discharges from bedrock or through tributaries which themselves are supplied by groundwater. The exact volume of water that groundwater discharge contributes to the five Great Lakes is unknown. The International Joint Commission (IJC) estimates that half of the total streamflow entering the Great Lakes from the U.S. is contributed by groundwater. Based on preliminary estimates from Lake Michigan, the IJC reports that direct groundwater discharge to the Lakes may be as much as 18 percent of the contribution of tributary flow into the Lakes. Also of critical importance is the role of groundwater in maintaining the Great Lakes Basin's streams and rivers. Groundwater discharge accounts for approximately half of the Basin's annual streamflow as well as a very significant portion of water in the Basin's upland lakes and wetlands.

7. Why is groundwater essential for wetlands?

Like windows in the water table, wetlands are low-lying areas where the ground surface is below/intersects the water table (uppermost level of groundwater) and are wet for at least part of the year. Wetlands (including swamps, marshes, bogs, and fens), not only depend on this ground-water discharge, but may also provide critical recharge areas for groundwater when the water table is low.

The Basin's abundant wetlands play many other important ecological roles, including: reducing the risk of flooding by storing water; improving water quality by filtering sediments, nutrients, and contaminants; reducing shoreline erosion; and providing unique habitat for numerous plants and animals. In summary, changes in either the quality or quantity of groundwater can severely impact the health of wetlands, which in turn are critical for maintaining a healthy groundwater and ecological system.

8. How does groundwater affect the wildlife ecology of the Great Lakes?

Groundwater, via the hydrologic cycle, is essential to the health of Great Lakes wildlife, including deer and other large mammals, fish, ducks, geese, and other migratory birds, shorebirds and small mammals such as mink, otter, muskrat, etc. All of these animals depend on fresh, abundant water not only for their sustenance, but as a critica part of their habitat. These water habitats or in some cases, "watering holes," such as wetlands, streams, rivers, lakes, and spring all depend on consistent supplies o groundwater discharge to maintain thei water levels. Groundwater is especially criti

Wetland in Ohio. Source: Judy Anderson

cal during dry periods when these surface water bodies are entirely dependent on groundwater discharge.

B. GROUNDWATER USAGE

Groundwater is appropriately regarded as the Great Lakes region's greatest "hidden asset." Groundwater resources significantly impact the physical health, economic well-being and quality of life of more than 45 million residents. In the U.S. and Canada, billions of gallons of groundwater are withdrawn daily in the Great Lakes region to meet a variety of domestic, industrial, commercial and agricultural uses. It is anticipated that our reliance on groundwater usage will increase in future years to accommodate population shifts, development pressures and the demands of an increasingly water-dependent regional economy.

9. What are the economic implications of groundwater contamination?

Economic development in the Great Lakes region is greatly dependent on the quality and quantity of available groundwater. Throughout the region, however, groundwater contamination poses a wide range of economic costs for business and local communities. Of particular concern for the future of economic development is the potential loss of property values, tax revenues, and business development due to groundwater contamination. See Case Study, "Minnesota: Economic Implications of Groundwater Contamination to Companies and Cities."

On the national scale, the U.S. EPA has estimated that the total current cost of groundwater contamination from just nine major point source polluters exceeds $28 billion. Determining the exact economic value of groundwater is not simple. Groundwater value includes: benefits associated with current uses; potential benefits of all future uses; and benefits that are inherent to groundwater because it maintains the region's ecosystem. The latter two categories are particularly difficult to quantify or estimate. Table 2-2 lists some of the costs associated with groundwater contamination.

The economic effects of groundwater contamination vary considerably from one location to the next. In any particular situation, the impacts and ability to effectively respond depend on the physical character of the groundwater system, the extent, location and type of contamination, and the time passed before the contamination is detected. Groundwater contamination may affect very few people or it may spread rapidly and cause extensive damage to a community's water supply. Groundwater contamination that remains undetected has the potential to cause particularly serious health and environmental effects. Chapter 3 presents an overview of the physical characteristics of groundwater contamination.

Groundwater Contamination poses a wide range of costs for residents.
Source: Clinton River Watershed Council

Case Study — Minnesota: economic implications of groundwater contamination to companies and cities

By their own estimate, the cost of groundwater contamination to 35 Minnesota cities and companies exceeded $67 million in 1988 and continues to increase. These costs are merely the tip of the iceberg of a regional and national problem with staggering economic, social, and environmental implications. Most of the cases entailed years of dangerous disposal practices that threatened municipal and private drinking water supplies. This conservative cost estimate did not consider the current status of many contaminated sites nor a $13 million estimate of job losses owing to loss of development potential in prime commercial property in just one city. For the companies surveyed, major costs of groundwater contamination included:

- *$21 million in site cleanup and remediation*
- *$13 million in consulting services and staff time*
- *$7 million in soil and water testing*

For the cities surveyed, the major costs of groundwater contamination included:

- *$8 million in lost tax revenue due to real estate devaluation (5 cities)*
- *$8.4 million on new equipment and water treatment (7 cities)*
- *$2.5 million on cleanup and remediation (6 cities)*

Adapted from *Economic Implications of Groundwater Contamination to Companies and Cities*, Freshwater Foundation special report, funded by the Blandin Foundation, 1989.

In small communities, groundwater contamination creates particular challenges. Highly dependent on a favorable business environment and a limited tax base, the resources of many communities are increasingly stressed by growing liability and high cost of groundwater cleanup and remediation. The high cost of groundwater cleanup makes the reuse and redevelopment of contaminated sites economically prohibitive. This situation encourages abandonment of previously productive sites and alters the pattern of economic development. Small cities face a greater likelihood of business relocation/abandonment and are particularly vulnerable to the resultant loss of jobs and tax revenue.

With more groundwater monitoring occurring, additional cases of contamination from past and present practices will be revealed. Cleaning up even relatively minor groundwater contamination sites is a very expensive, slow, and uncertain process. Once contaminated, groundwater may remain unusable for hundreds or even thousands of years. Businesses in the Great Lakes region have already spent millions of dollars in cleanup. These expenses are not just short-term concerns; the potential for real estate devaluation and other future liabilities makes groundwater contamination a long-term liability.

Some Great Lakes states have "polluter pay" legislation which provides businesses with a strong incentive to protect ground-water. In the future, good preventive measures will be needed to protect groundwater quality, a sound investment when one considers the staggering costs of clean-up. Recognizing that prevention of groundwater contamination is more cost effective than groundwater clean-up, communi-ties' need for long-term water management to sustain their economic base is evident. This goal requires cities and industries to work together for groundwater protection in recognition of their economic interdependence.

The economic importance of groundwater cannot be overstated. To fully appreciate the region's economic dependence on clean abundant groundwater supplies it is necessary to examine groundwater supply usage by all sectors of society: domestic, public municipal, industrial, agricultural, and natural resource development.

Domestic Water Supply

10. How many people in the Great Lakes region depend on groundwater for their drinking water supply?

An estimated 45 million people in the Great Lakes states and provinces, a full 53 percent of the population, are completely dependent on groundwater for their drinking water supply. Almost all of the region's rural residents depend on private (self-supplied) groundwater wells (see Table 2-3).

Domestic groundwater uses include myriad household purposes such as (in order from

Table 2-2
Costs associated with groundwater contamination

- **Non-detection;** although the costs are difficult to quantify, there may be severe impacts on human health and the ecosystem.
- **Detection;** biannual testing of private wells ($100–300); for larger areas, new monitoring wells ($2,000–5,000 per well) plus possibly costly sampling programs.
- **Containment and Remediation;** highly variable, estimated average cost of remediation efforts at Superfund sites is $8 million.
- **Treatment;** highly variable depending on type of treatment and whether it is a central or household system, range is from $2–723 per household per year.
- **Replacement;** new well for single household is approximately $5000–7000, depending on depth, diameter, and site characteristics; private hook-up to public water system ranges from $12,000 up — highly dependent on location.

Adapted from *Economic Implications of Groundwater Contamination to Companies and Cities*, Freshwater Foundation, 1989.

most to least consumption): flushing toilets; bathing and showering; drinking, washing hands, brushing teeth; laundering clothes; washing dishes, cooking; and outdoor uses such as watering lawns and gardens.

Other self-supplied groundwater users frequently categorized as "domestic" include commercial users such as restaurants, hotels, motels, and civilian and military institutions. Estimates by the U.S. Geological Survey (USGS) indicate that commercial users in thereat Lakes states relied on groundwater for more than 50 percent of their total water supply in 1990.

Table 2-3
Estimated populations in the Great Lakes states and Ontario that depend on groundwater as a primary water supply

Jurisdiction	Population (millions)	Dependent on Groundwater (millions)	(percentage)
Pennsylvania	11.9	10.7	90
Minnesota	4.2	3.2	75
Wisconsin	4.8	3.2	67
Indiana	5.5	3.2	59
Michigan	9.2	4.6	51
Ohio	10.8	5.4	50
Illinois	11.6	5.6	48
New York	17.8	6.2	35
Ontario	9.3	2.8	25
TOTAL	85.0	45.0	53

Adapted from *1991 Report to the International Joint Commission*, Great Lakes Science Advisory Board.

Public/Municipal Water Supply

11. What is meant by public/municipal water supply?

Public/municipal water supply is water withdrawn by public and private water suppliers and delivered for a variety of uses including residential, commercial, industrial, and public water use.

12. How much does the region's public/municipal water supply depend on groundwater?

In 1990, approximately 25 percent of the water withdrawn for public/municipal water supply in the Great Lakes States came from groundwater. According to the USGS, groundwater supplied by public water suppliers served an estimated 2,860,000 U.S. Great Lakes Basin residents in 1985.

Industrial Water Supply

13. How dependent on groundwater is manufacturing in the Great Lakes region?

Approximately one-fourth of manufacturing water demand in the Great Lakes states is satisfied from groundwater sources. Industrial water demand varies widely across the spectrum of manufacturing operations and quality requirements are also different depending on the purpose for which the water is to be used. The uniform temperature of groundwater and its relatively stable chemical characteristics provide particular advantages for certain industrial uses.

Industrial operations located near the Great Lakes usually rely on surface water or municipal water supplies. The more removed from the Great Lakes or major rivers, the greater is the reliance of industry and other sectors on groundwater.

Each production day, industries in the Great Lakes states withdraw approximately 970 million gallons of groundwater. These "self-supplied wells," in contrast to public water system wells, are independently owned and managed (see Figure 2-3).

Agricultural Water Supply

14. How much groundwater is used for irrigation in the Great Lakes states?

Each day in 1990, approximately 543 million gallons of groundwater were used for irrigation in the Great Lakes states. This groundwater supply ensures higher productivity by increasing the number of possible plantings per year and reducing the threat of crop failure during drought periods. The region's agricultural comunity also relies heavily on ground-water for livetock production and day-to-day operations.

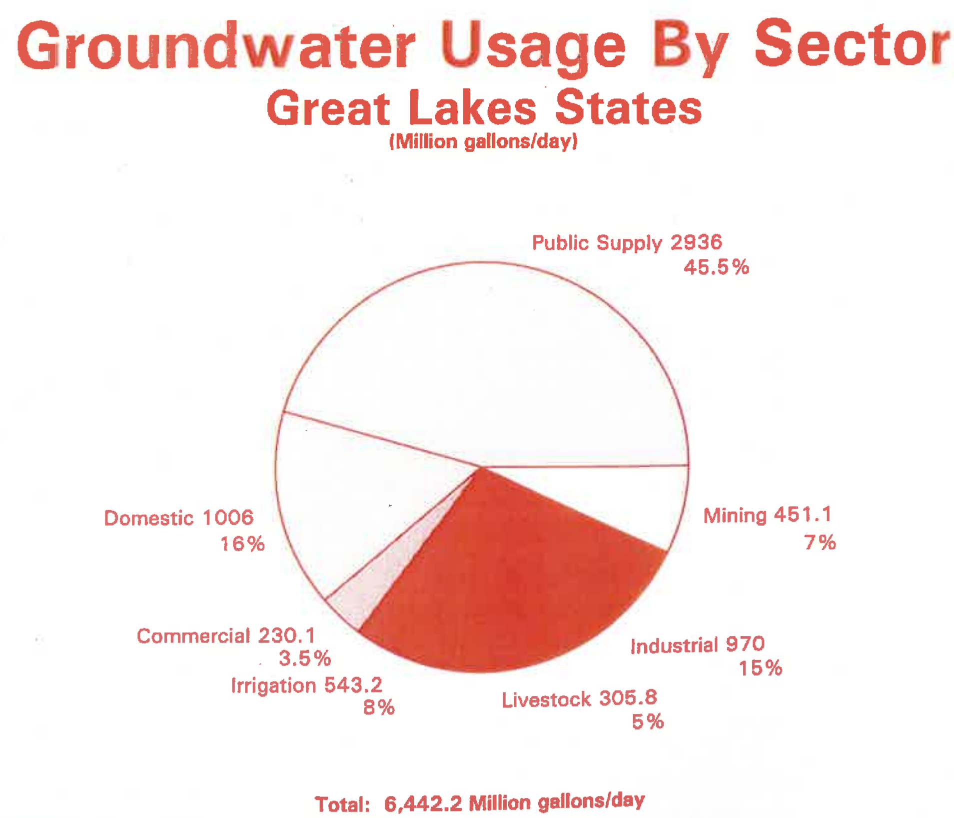
The region's agricultural comunity relies heavily on groundwater for irrigation of cropland.

Water Supply for Natural Resource-Based Industries

15. Does the region's mining, forestry, gas and oil development depend on groundwater?

It is difficult to estimate the amount of water used in this category because in many cases water is an impediment or by-product of the extraction process and, thus, little attention is paid to the quantity withdrawn. Nonetheless, groundwater is needed in very significant quantities as part of the mining process, both for the drilling process (in oil and gas development) and for washing and milling of minerals. Gas and oil operations will frequently drill water wells on site to supply their needs as the use of surface waters is regulated to prevent contamination of groundwater in the drilling process.

Figure 2-3
Groundwater usage by user sector



Source: U.S. Geological Survey Circular 1081, 1990

Chapter 3

LAND USE ACTIVITIES: IMPACTS ON GROUNDWATER QUALITY AND QUANTITY

There is growing concern over groundwater contamination and the tremendous, long-term impacts which various land uses can have on the quality and quantity of groundwater supplies. Understanding the connection between land use and groundwater quality is the first step toward protection of this critical resource.

This chapter begins with an overview of groundwater contamination issues, answering critical questions about groundwater quality, followed by a discussion of contaminant sources associated with land prevention practices, four broad categories of land use activities: waste management; materials storage and handling; urban and rural nonpoint pollution, and natural resource use and development. The final section of the chapter deals with the development of our groundwater resources, considering questions of water supply planning and quantity.

A. OVERVIEW OF GROUNDWATER CONTAMINATION

1. Is groundwater naturally pure?

Some Great Lakes region residents can drink groundwater directly from their well, while others must first filter or disinfect it to remove naturally occurring groundwater contaminants including organic substances, sediments, minerals, bacteria, and viruses. Natural water quality concerns are often due to "mineralized" groundwater that contains dissolved minerals and salts. (See Table 3-1)

All groundwater contains some dissolved minerals or salts. Whether these substances are just a nuisance or make the water unusable, depends on their type and quantity as well as on the water's intended use. Far from being a threat, many naturally occurring substances in groundwater are often essential for good health. However, some minerals give water undesirable properties such as unpleasant taste, odor, appearance, or hardness. Water hardness is a common water quality problem usually caused by dissolved calcium and magnesium. It may cause soap and scale deposits in plumbing and appliances as well as decrease the cleaning efficiency of soaps and detergents.

Many Great Lakes residents can drink pure refreshing groundwater directly from their well.
Source: *Groundwater Education in Michigan*, Michigan State University

Mineralized groundwater that is unacceptable for one use, such as drinking, may be perfectly acceptable for another, such as industrial cooling and processing. The mineral

Table 3-1
Naturally occurring substances in groundwater*

Mineral/Inorganic		
• Iron	• Calcium	• Magnesium
• Bicarbonate	• Sodium	• Sulfate
• Silicon	• Chloride	• Carbonic acid
• Carbonate	• Nitrate	
Bacterial or Pathogenic		
• Fecal coliform	• Giardia Hepatitis	
Dissolved Gases		
• Methane	• Radon	
• Hydrogen sulfide		

* This is not a complete list; it is only representative of some of the most common components found in groundwater.

content, or total dissolved solids (TDS), of groundwater depends on the amount of time it remains in the ground, the distance it travels, and the solubility of the rock or soil it passes through. In general, the greater the depth of groundwater, the higher its TDS. Chapter 2 discusses groundwater quality in the Great Lakes region.

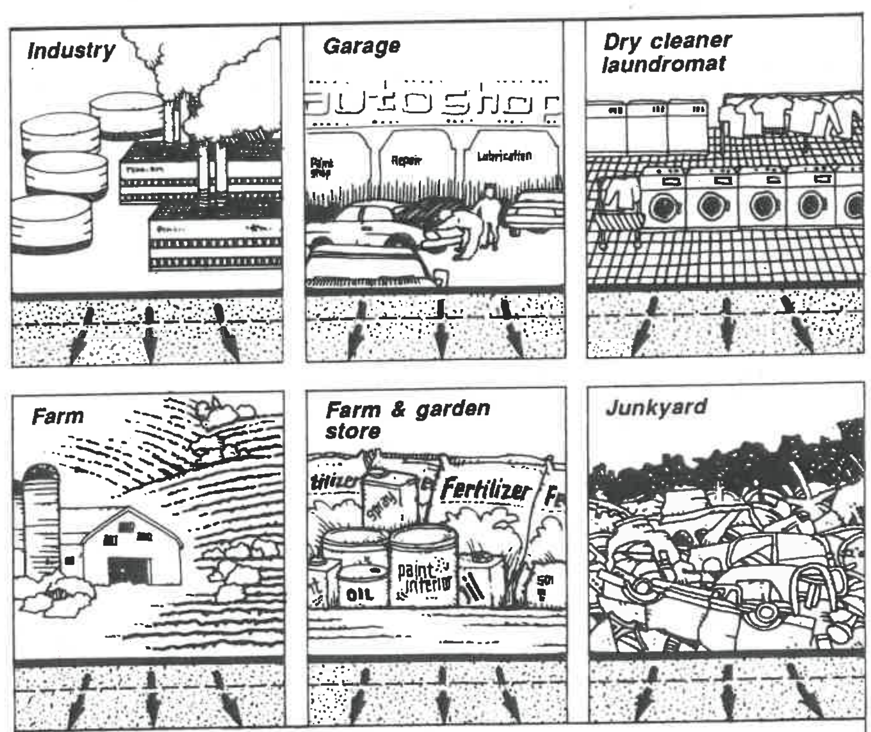
2. How do humans affect groundwater quality?

Many common materials such as gasoline, oil, paint, pesticides, fertilizers and industrial solvents are potential groundwater contaminants. When these and other potentially hazardous materials are spilled or improperly used or disposed of, they may cause contamination of groundwater (see Figure 3-1). The source of the contamination may originate from activities either on the ground surface or in the ground, above or below the water table. Table 3-2 shows examples of activities at each level which can contaminate groundwater. The most frequent causes of groundwater contamination, however, are ordinary land uses such as septic tanks, landfills, and agriculture. Once a potential contaminant has been released into the environment, it doesn't magically disappear. Although the layers of soil and rock above the groundwater were, until recently, considered a natural filter and protection against groundwater contamination, the vulnerability of groundwater to contaminants passing through all of these "filtering layers" is now well estabished. Various proceses, including filtration, dilution, oxidation, and biological decay, do act on contaminants as they move with infiltrating water through the unsaturated layers of soil and rock toward the groundwater table. These processes do not, however, effectively prevent contamination by the multitude of hazardous materials released into the environment by common urban and rural land use activities. In fact, many hazardous materials kill the natural microorganisms in the soil which help to break down other potential groundwater contaminants such as septic tank effluents.

3. What are the most serious groundwater contaminants?

The most serious groundwater contaminants, which pose a significant health risk, come from human activities and land uses (see Table 3-3). Most of these contaminants are compounds containing carbon, known as synthetic organic chemicals. Approximately 70,000 types of these chemicals are under common industrial and commercial use and the numbers increase by about 1,000 each

Figure 3-1
Contamination is caused mainly by improper practices



CONTAMINANTS: ● Diverse; includes chemical cleaning compounds, metals, petroleum, fertilizers, paint products, etc.

Source: *Groundwater Contamination*, Raymond, Lyle S., Jr. New York State Water Resources Institute, Center for Environmental Research, Cornell University, 1988

Table 3-2
Human-Generated Sources of Groundwater Contamination

Ground Surface

- Infiltration of polluted surface water
- Land disposal of wastes
- Accidental spills
- Airborne particles
- Sewage sludge disposal
- De-icing salt (use & storage)
- Animal feedlots
- Fertilizers & pesticides
- Dumps

Above the Water Table

- Septic tanks, cesspools, privies
- Holding ponds & lagoons
- Sanitary landfills
- Waste disposal in excavations
- Underground storage tank leaks
- Underground pipeline leaks
- Artificial recharge
- Sumps and dry wells
- Graveyards

Below the Water Table

- Waste disposal in wells
- Drainage wells and canals
- Underground storage
- Mines
- Exploratory wells
- Abandoned wells
- Water-supply wells

Adapted from *Handbook - Ground Water and Contamination, Vol. 1*, U.S. EPA, 1990.

year. Among those most often occurring in randomly selected public groundwater supply systems are chemical solvents commonly used by dry cleaning and industrial establishments such as trichloroethylene (TCE) and perchloroethylene (PCE).

Other common groundwater contaminants include pesticides, pathogens (bacteria and viruses), and nitrates. A 1990 survey by the U.S. EPA estimated that over 10 percent of community water supply wells have detectable levels of pesticides. Although these detectable amounts may be "insignificant" in terms of what we now know, much uncertainty remains about the long-term, cumulative, and combined effects of these and other chemicals on public health. In addition, the widespread occurrence and persistent toxicity of pesticides is of great concern for public health.

Perhaps the most common groundwater contaminant in the Great Lakes region is nitrate. Nitrates originate mostly from septic tank systems, agricultural fertilizers, and livestock operations. They have been found in excess of the legally acceptable or maximum contaminant level (MCL) in as many as 250,000 wells (about 2 percent) in the region. Nitrates cause a condition known as blue baby syndrome in infants and have also been associated with human birth defects, high blood pressure, and certain types of cancer.

Table 3-3
Major Types* of Groundwater Contaminants In the Great Lakes Region

Organic Chemicals

- Industrial solvents (e.g., trichloroethylene (TCE), vinyl chloride)
- Petroleum products (e.g., benzene, toluene)
- Pesticides (e.g., aldicarb, alaclor)

Inorganics

- Nitrates
- Arsenic
- Sulfates
- Fluorides
- Brine/Salt
- Chlorides

Other

- Metals
- Bacteria
- Radioactive Materials (some from natural mineral deposits)

*Note: This is not a complete list.

Adapted from *Overview of State Groundwater Program Summaries*, Volume 1, U.S. Environmental Protection Agency, March 1985.

4. What are the most common sources of groundwater contamination in the Great Lakes region?

Because there are so many types, sources, and still unidentified causes of groundwater contamination, it is difficult to specify the most common contamination sources. In this light, it is helpful to categorize groundwater contamination sources as being either diffuse (nonpoint) sources or point sources, such as waste sites or industrial waste discharges. Contamination of groundwater from nonpoint sources is probably most common and includes urban and rural runoff from roadways and agricultural fields, and septic systems.

While point sources of groundwater contamination contribute less overall quantity, they commonly create much higher concentrations of contaminants and thus pose a particularly serious problem for public health and the environment (see Table 3-4).

Table 3-4
Major Sources of Groundwater Contamination in the United States

- Septic Tanks
- Municipal Landfill
- On-Site Industrial Landfills
- Other Landfills
- Surface Impoundments
- Oil and Gas Brine Pits
- Underground Storage Tanks
- Injection Wells
- Hazardous Waste Sites
- Agricultural Activities
- Land Application/Treatment
- Highway De-icing Salts
- Other (e.g., abandoned wells, inadequately constructed wells, improperly plugged wells, mining activities, oil and gas activities, petroleum product storage, accidental spills and leaks

Adapted from *Overview of State Groundwater Program Summaries, Volume 1*, U.S. Environmental Protection Agency, March 1985.

5. Who is to blame for groundwater contamination?

As the impacts of groundwater contamination on public health, our economy, and our natural environment become more serious, our tendency to point fingers may increase. All segments of society, however, have been guilty of ignoring the long-term consequences of our land use activities on groundwater. Thus, a more helpful and realistic approach might be to examine what each of us can do, whether as citizens and consumers, or as representatives of business and industry, government, and educational institutions, to protect groundwater and see that the next generation is not left with a legacy of depleted and polluted groundwater resources.

6. How do contaminants move in groundwater?

Once a contaminant has seeped into groundwater, its movement is influenced by its solubility, density, and the direction of groundwater movement. Dense contaminants will sink to the bottom and lighter ones will float to the top of an aquifer. Non-water soluble contaminants are not very mobile within the groundwater zone. However, many groundwater contaminants with extremely low water solubility, such as man[y] toxic pesticides, are so poisonous that the[y] still may exceed maximum allowable concentra[-]tion limits (MCLs) for drinking water. In[-]soluble, lighter than water petroleum products such as those seeping downward from spills o[r] leaking underground storage tanks, remain i[n] the unsaturated zone above the water tabl[e] and can still be drawn into a well.

Contaminants are generally carried alon[g] with groundwater at very slow velocities (10 1000 feet per year) and do not disperse o[r] become diluted. As a result, most con[-]taminants move through the aquifer as a dis[-]tinct contaminant body or plume.

7. How large an area can be effected by groundwater contamination?

Since most wells draw water from a relativel[y] local area of recharge, contaminatio[n] problems can usually be traced back to loc[al] contamination sources within this "zone c[of] contribution." However, due to the grea[t] variability in hydrogeologic settings and th[e] distinct rate of transport of different co[n]taminants in groundwater, it is very difficu[lt] to generalize. In some circumstances, groundwater contamination does spread rapidly over large areas.

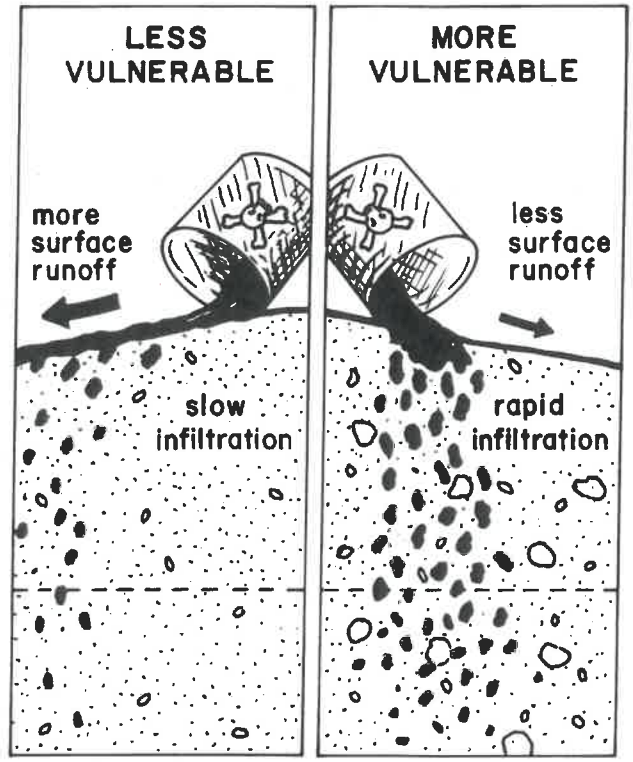
It is the relatively localized nature of groundwater contamination that makes control of land uses in the vicinity of wells so important for preventing drinking water contamination. This phenomenon also explains why well water/groundwater can be contaminated in one location and remain uncontaminated only a short distance away.

8. What determines the vulnerability of an aquifer?

While all aquifers have the potential to be contaminated, some are more vulnerable to contamination than others. Those that are most vulnerable may become rapidly contaminated from even relatively small discharges of hazardous materials on the ground surface. Factors which determine an aquifer's vulnerability to contamination from the surface include 1) the depth of the aquifer (depth to water from surface), 2) the nature of the materials overlying the aquifer (soil type), and 3) the nature of the aquifer itself. In general, the shallower the aquifer the more vulnerable it is to contamination (See Figure 3-2). However, the permeability and make-up of the soil and rock materials overlying the aquifer control the speed and degree of degradation of contaminants as they infiltrate down to groundwater. Thus, shallow aquifers overlain by highly permeable sands and gravels are particularly vulnerable to contamination.

The permeability of the aquifer itself is also an important determinant of its vulnerability. In highly permeable aquifers, contaminants may be rapidly transmitted to nearby wells, streams, lakes, and wetlands which the aquifer supplies. Much of the Great Lakes region consists of highly permeable sand, gravel and fractured dolomite or limestone aquifers and are extremely vulnerable to groundwater contamination.

Figure 3-2
Aquifer vulnerability



Source: *Aquifers*, Raymond, Lyle S., Jr. New York State Water Resources Institute, Center for Environmental Research, Cornell University, 1990

9. How does groundwater contamination affect surface water in the Great Lakes region?

Numerous cases of surface water being contaminated by groundwater discharge have been documented in the Great Lakes region.

According to the International Joint Commission (IJC), "contamination of groundwater from agricultural fertilizers and pesticides poses the possibility of very significant pollution of the Great Lakes via groundwater...."

The most alarming example of surface water contamination from groundwater in the region is the Niagara River. The IJC estimates that every day 394 pounds (178 kilograms) of organic chemicals originating from disposal sites near Niagara Falls enters the Niagara River via groundwater discharge.

Private Well Water Supply Testing.
Source: Wisconsin Department of Natural Resources

10. How is groundwater contamination detected?

Unfortunately, groundwater contamination often remains undetected until the problem has already affected its users. A comprehensive groundwater monitoring program to detect contamination before it affects a community, requires extensive, on-going testing (See Table 3-5). Generally, because of limited funding and personnel, such comprehensive testing programs do not exist. Increasingly, however, state and federal agencies are legally required to perform groundwater monitoring around high risk land uses such as waste disposal sites. The responsibility to protect and monitor groundwater quality in private wells is up to the individual owner.

Many public health departments provide water testing services for common substances such as nitrates and fecal coliform bacteria. However, commercial laboratories must be used when analyzing for synthetic organic chemicals. The process is expensive, and due to the abundance and diversity of possible groundwater contaminants, individual tests

Measuring Groundwater Contaminants

Groundwater contaminants are measured in terms of their concentration; quantity (weight) of contaminant per volume of water. Over the past twenty-five years, the detection limits for contaminants have become increasingly small, allowing chemists to detect contaminants in groundwater samples in exceedingly small concentrations.

Units of Measure for Concentration

One milligram per liter (mg/L) equals one part per million (ppm)

One microgram per liter (ug/L) equals one part per billion (ppb)

Table 3-5
Groundwater Monitoring

Groundwater monitoring, using monitoring wells and exploratory borings, is a common method of hydrogeologic investigation and is commonly required as a method of on-going monitoring at contamination sites. The process is very expensive and time consuming. At a minimum, a groundwater monitoring program includes an investigation of: the depth to groundwater, aquifer characteristics, direction and rate of flow, and chemical quality of the water. Groundwater monitoring can be performed to:

1. Assist in **pollution prevention**; common with new landfills and underground storage tanks;

2. Assist in **pollution response**; to determine the contaminant source, extent of contamination, and potential for mitigating and/or cleaning up once the contamination has occurred; and

3. Assist in **water supply planning**; to determine proper resource development and resolve potential conflicts.

are required to detect each of a narrow range of similar compounds. Consult your telephone directory to find local water quality laboratories.

11. Can contaminated groundwater be cleaned up?

Once groundwater becomes contaminated, it may remain that way for hundreds or even thousands of years. Groundwater contaminants generally move very slowly, and may be partially or completely retained by the aquifer materials. Although it is possible in some cases to clean up contaminated groundwater, the technical uncertainties and extraordinary cost of such work makes it prohibitive. While new technologies using bioremediation, new pumping techniques, etc., are promising, they offer no cure-all to the problems of groundwater contamination. Groundwater remediation and cleanup programs are plagued by technical uncertainties including: direction and rate of contaminant movement, determination of extent and source(s) of the contamination, and feasibility of technical approaches.

Due to the high cost of comprehensive groundwater monitoring as well as the costs and uncertainties associated with cleanup, the only sensible approach to managing groundwater resources is planning for groundwater protection. Chapter 4 discusses issues and opportunities in groundwater protection.

B. WASTE DISPOSAL AND MANAGEMENT

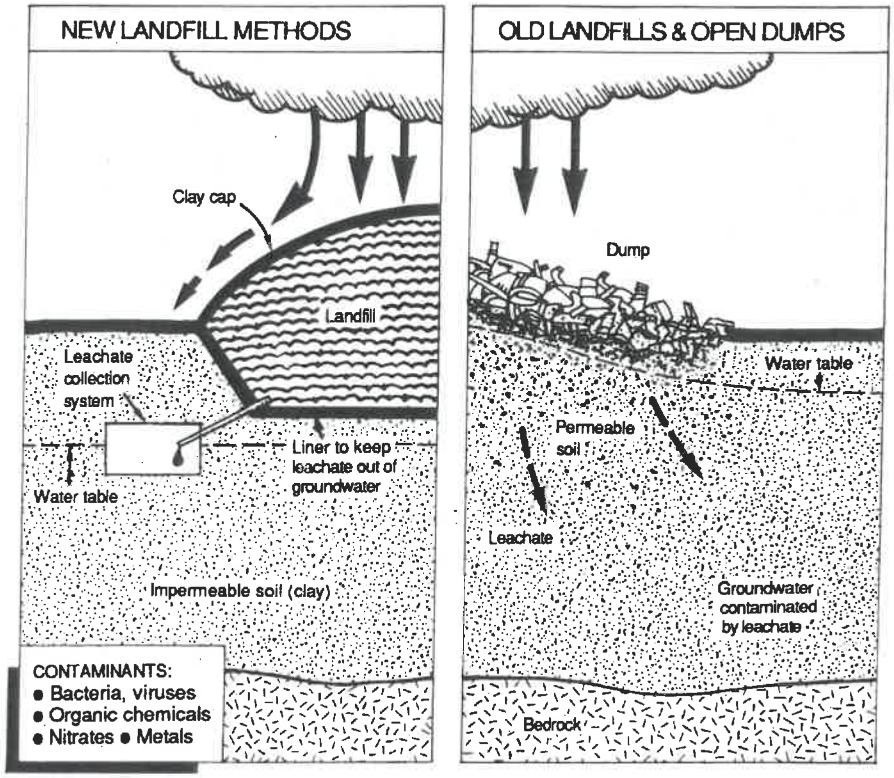
The disposal and proper management of hazardous, industrial, and municipal wastes has become a growing problem throughout the United States and Canada. Not only are there serious problems with finding adequate and socially acceptable land areas to dispose of our society's wastes but there is also the associated problem of groundwater contamination.

In the Great Lakes region, waste disposal practices, including the use of landfills, surface impoundments and deep-well injection of waste, provide the most well known sources of groundwater contamination. Of particular concern for groundwater contamination are the thousands of active and abandoned leaking, hazardous waste sites. A substantial percentage of the highest priority sites (National Priority List) identified under U.S. federal Superfund legislation (Comprehensive Environmental Response, Compensation, and Liability Act), are in the Great Lakes region.

12. What is a landfill and how does it affect groundwater?

Landfills are repositories of miscellaneous solid and liquid wastes generated by both municipalities and industry (see Figure 3-3). Municipal or sanitary landfills are generally constructed by placing waste material in excavations and covering it daily with soil to reduce odor and scavenging by animals. Until the 1970s, landfills accepted all wastes; making virtually no distinction between the miscellaneous domestic garbage and hazardous liquid and solid wastes. The indiscriminate landfill disposal of these materials has created a tremendous, nationwide problem of landfills leaking contaminated water or leachate. Leachate is formed when rainfall and surface water infiltrate into the dump picking up contaminants as they move through the waste.

Figure 3-3
Changing landfill engineering methods



Source: *Groundwater Contamination*, Raymond, Lyle S., Jr. New York State Water Resources Institute, Center for Environmental Research, Cornell University, 1988

Because of the enormous numbers of possible contaminants in a landfill, the chemical content of this leachate is highly variable. Common leachate constituents include, metals, bacteria, viruses, organic chemicals, and nitrates. Old, abandoned landfills are sometimes first identified when these substances show up in local wells or discharge via ground-water into streams or wetlands. Even after a landfill has long since been abandoned, leachate may continue to contaminate local groundwater supplies for an indefinite period.

13. How is modern engineering design of landfills helping to prevent groundwater contamination?

Although there is probably no failsafe landfill, careful engineering of new landfill facilities incorporates three essential construction elements: 1) an impermeable clay cap or cover to stop infiltration of water from the surface; 2) an impermeable lining at the base of the excavation to hold in leachate, and 3) a leachate collection system which drains and collects all leachate for proper disposal. Many existing landfills do not use such state-of-the-art environmental controls. Having been grandfathered when existing leachate collection requirements took effect, these landfills will continue to contaminate groundwater even after they have been closed down in the next decade. When you add to this the consideration of high costs, increasing volumes of solid waste, and limited space for new landfills, it is easy to see why many localities are looking for alternative waste management approaches (see Table 3-6).

14. What is "Alternative waste management" and how can it help to protect groundwater?

The old bury-it-all system of waste management is rapidly disappearing as environmental, social, and economic factors are forcing communities and individuals to confront the waste management crisis. Innovative options for waste management incorporate a whole new waste ethic in which communities are selecting the best alternatives and combinations of both technical and non-technical approaches to waste management.

Table 3-6
Examples of Pollution Prevention Techniques

Source Reduction
Ways to reduce the amount of waste generated include:
- Maintain better inventory and control of raw materials
- Use detergents in place of solvents where possible
- Segregate wastes into recyclable and non-recyclable portions
- Substitute water-based paints for solvent-based paints
- Give excess paints to customers as touch-up paints
- Use solvent sinks, hot tanks, and jet sprayers
- Improve general housekeeping:
  - Operate equipment properly
  - Avoid and limit leaks and spills
  - Improve product transfer and leak collection procedures

Recycling and Resource Recovery
Ways to recycle waste fluids or recover usable resources include:
- Contact local recyclers for reclamation of waste oil, anti-freeze, transmission fluid, solvents, and lead-acid batteries
- Use low-cost gravity separation to reclaim solvents
- Re-use waste materials (solvents, automotive fluids) when possible

Wastewater Treatment
Some low-cost ways to treat wastewater on-site for reuse or disposal include:
- Chemical neutralization and precipitation
- Activated carbon absorption
- Solvent extraction
- Stabilization/Solidification
- Incineration
- Solid/Liquid separation

Adapted from *Shallow Injection Wells And How They Affect Drinking Water*, a pamphlet by U.S. EPA - Region IX, 1990.

Non-technical approaches include programs that reduce the volume of waste headed to landfills through recycling, waste reduction, material recovery, burning/incineration, and central composting. Technical approaches include engineered landfills (as mentioned), waste-to-energy systems which produce energy by incinerating solid waste, chemical stabilization which seeks to stabilize waste for safer storage, and biological degradation which seeks to degrade pollutants or eliminate their volume through microbial action.

The Roman Empire Lives – and Leaches – On

Old abandoned landfills are likely to be a cause of continuing concern, because they generate leachate for a considerable length of time after actual dumping operations have stopped. A landfill used during the era of the Roman Empire, for example, was recently found to still produce leachates.

– Ground Water: A Non-Technical Guide, 1982

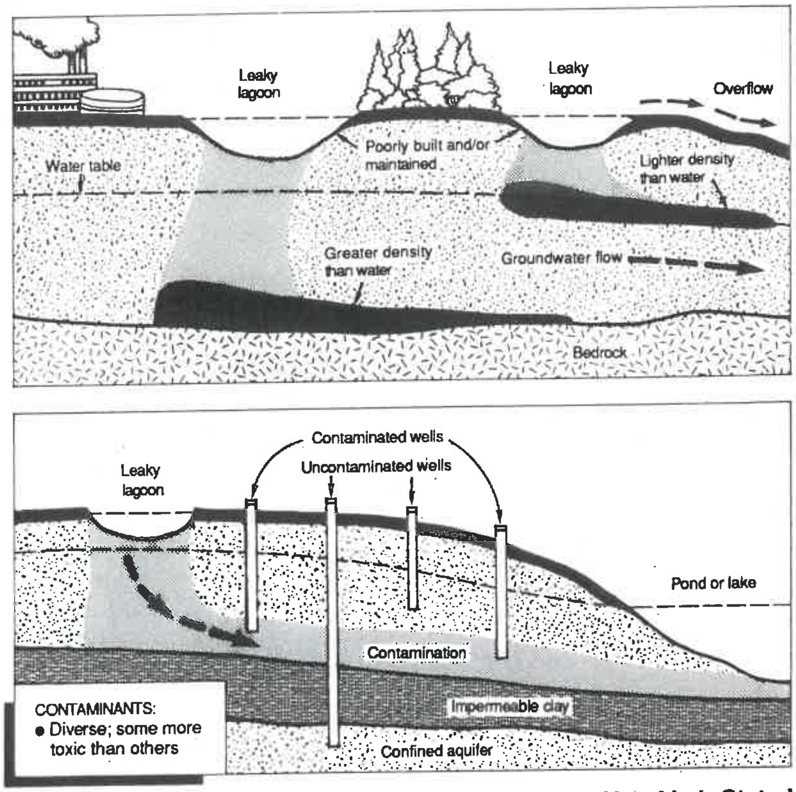
15. **What other preventive measures are available to make landfills less prone to contaminating groundwater?**

In addition to properly engineered construction, maintenance, and operation, landfills should not be located in sensitive groundwater areas. A regular program of groundwater monitoring and inspection should be maintained. Education programs which seek to reduce waste by promoting recycling should be combined with education about household hazardous waste reduction and waste reuse and recovery. Chapter 6, "Community and Citizen Involvement: What You Can Do," discusses the role of community and citizen education in more detail.

16. What are surface impoundments and how do they affect groundwater?

Surface impoundments include ponds or storage lagoons which are generally used by industry, oil and gas producers, agriculture, municipalities, and private businesses to treat, store, and dispose of both hazardous and non-hazardous liquid wastes. Ideally, the impoundments are lined with impervious clay or plastic liners. However, poor management, infrequent inspection, or old, failing liners can lead to groundwater contamination (see Figure 3-4).

Figure 3-4
Surface Impoundments



Source: *Groundwater Contamination*, Raymond, Lyle S., Jr. New York State Water Resources Institute, Center for Environmental Research, Cornell University, 1988

17. What is deep well injection and how does it affect groundwater?

Deep well injection is a method of waste disposal that is sometimes used by industry and municipalities. In the past, such wells were entirely unregulated and hazardous wastes were injected directly into or above drinking water aquifers. Such blatantly dangerous disposal methods are now banned and the U.S. EPA's Underground Injection Control (UIC) Program now works with each state to regulate all deep well injection. Wells used for hazardous wastes are usually very deep. In Michigan, for example, wells penetrate between 2,900 and 5,800 feet below the earth injecting liquid wastes under pressure into the pore spaces of permeable sandstone or limestone formations.

The major concerns in protecting groundwater are: 1) proper well construction and maintenance; 2) improperly constructed local wells which may channel the waste away from the intended disposal location; 3) confining layers which are fractured or otherwise permeable; and 4) lateral displacement. In the proper geological setting and with proper management, deep well injection is considered a safe and effective tool for waste management. Due to considerable uncertainty about subsurface geology, however, this is by no means a fail-safe waste disposal technology. This uncertainty makes it difficult to prove when an injection well has failed.

Gravity Never Sleeps

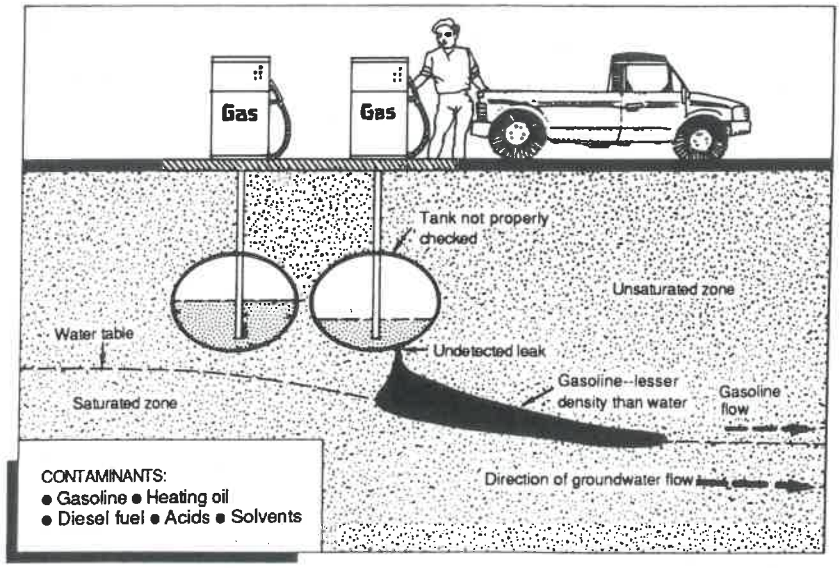
If there is a Murphy's law of groundwater contamination, it must go something like this: Whatever can get into the groundwater, will. Any substance left exposed to rain and moisture on the surface of the ground, or underground, will probably eventually be picked up and carried to groundwater through the natural process of recharge. Gravity never sleeps.

— *SAWARA Waterwords*
Southern Arizona Water Resources Association

C. HAZARDOUS MATERIAL STORAGE AND HANDLING

Groundwater contamination occurs not only from waste disposal practices but also as a result of the storage and handling of hazardous materials. Contamination of the groundwater may occur after the materials have been released either on the ground surface or by leaking underground storage tanks or pipelines in the subsurface. Contamination via the ground surface occurs most commonly due to accidents or spills during the transport or delivery of hazardous materials.

Figure 3-5
Underground storage tanks



Source: *Groundwater Contamination*, Raymond, Lyle S., Jr., New York State Water Resources Institute, Center for Environmental Research, Cornell University, 1988

18. What are leaking underground storage tanks and how do they affect groundwater?

Leaking underground storage tanks (LUST) have been gaining the attention of concerned health and environmental professionals throughout the Great Lakes region, as well as citizens who witness, with increasing frequency, the removal of leaking underground storage tanks at the corner service station (See Figure 3-5). Although most often used for gasoline storage at service stations, the tens of thousands of underground storage tanks in the Great Lakes region are also used to store diesel, fuel oil, acids, industrial solvents, and hazardous wastes.

Due to corrosion and old age (most have a 10-30 year lifespan), many thousands of these steel tanks are leaking or have leaked in the past. Unfortunately, leaks may go undetected for long periods until their contents seep into the soil, contaminating groundwater and finding their way into wells and basements. Over time even very small leaks can contribute a large volume of contaminants and destroy groundwater resources for a large population.

19. What is being done to prevent LUST?

Throughout the region, awareness is growing of the need to locate, remove, and monitor aging underground storage tanks before they begin leaking contaminants into groundwater. Protection of groundwater resources must begin with proper installation of non-corrodible tanks, maintenance, leak monitoring and careful inventory of tank volume. Abandoned tanks, which may still contain hazardous materials, should be located and either removed or filled with inert material, such as sand or cement.

Due the enormity of the problem—an estimated 400,000 underground storage tanks are leaking nationwide—the U.S. EPA regulates some tanks and assists the states in managing and cleaning up LUST.

20. What are transport or delivery spills and how do they affect groundwater?

Accidents are commonplace. However, when these mishaps involve the delivery or transport of hazardous materials (e.g., spills on the roadside or next to a storage tank), groundwater contamination may occur. Lack of proper training, inadequate equipment maintenance, inadequate spill containment facilities, or lack of spill response and cleanup procedures may worsen the resulting contamination.

21. What is done to prevent spills during transport, handling and delivery?

Considering the extraordinary volume of hazardous materials that are transported, delivered, and handled each day, planning for prevention of spills is a necessary component of any groundwater protection plan. Federal, state, and local governments employ a host of regulations ranging from strict federal transportation guidelines to local chemical management plans. Common to most regulations is the need for: proper employee training, equipment maintenance, inspection, spill containment facilities, spill response and cleanup procedures.

22. What is the concern with pipelines and how do they affect groundwater?

Just like leaking underground storage tanks, pipelines corrode with age and exposure to the elements. In addition, pipelines may have been improperly installed and maintained or be disturbed by vehicle-induced vibrations or tree roots. Regardless of the cause, a ruptured pipeline carrying such common liquids as gas, oil, or sewage may contaminate groundwater. Pipeline-related contamination poses similar prevention and remediation problems to those associated with underground storage tanks, but inspection and maintenance is complicated by the uncertain location and great length of many pipelines.

D. NATURAL RESOURCE USE AND DEVELOPMENT

The use and development of abundant natural resources in the Great Lakes region is a cornerstone of its economic and cultural character. Activities, such as farming, oil and gas production and mining, not only depend on groundwater supplies but also have significant impacts on groundwater quality. In 1989 alone, the U.S. portion of the region's agricultural lands generated $45 billion in gross sales of farm commodities. In 1991, Ontario had $5.1 billion (Canadian) in gross farm sales.

Oil and gas production is not always associated with the Great Lakes region. However, Michigan, Illinois, Ohio, Pennsylvania, and Ontario maintain significant reserves and production facilities. In 1988, the U.S. portion of the region produced 57.8 million barrels of oil, or 2.1 percent of total U.S. production. In 1991, Ontario produced nearly 1.5 million barrels of oil and approximately 418 million cubic meters of natural gas.

23. How does agriculture affect groundwater?

While agricultural productivity has increased tremendously since World War II, so has its reliance on an enormous variety and quantity of chemicals. Considering that agricultural lands in the U.S. portion of the Great Lakes Basin cover nearly 170 million acres (more than half of the total land area), it is no wonder that agriculture is one of the primary contributors to groundwater contamination (see Table 3-7). Of primary con-

Table 3-7
Factors Increasing the Potential for Groundwater Contamination by Pesticides

Pesticide Properties
- high solubility
- low absorption
- persistence

Soil Properties
- sand and gravel
- low organic content

Site Conditions
- shallow depth to groundwater
- wet climate or extensive irrigation
- depressions or flat areas where water collects

Management Practices
- poor timing with respect to climate
- over applicaion (rate too high or application too frequent)

Adapted form *Pesticides and Groundwater: A Guide for the Pesticide User*, a pamphlet by Cornell Cooperative Extension, 1989 cern are the impacts of pesticides and fertilizers on groundwater supplies and public health.

Agricultural chemicals have been detected in groundwater all across the United States. A 1990 U.S. EPA survey of community water wells revealed that over 10 percent of the wells tested contained traces of one or more pesticides and that approximately 61,000 rural, domestic wells contain at least one pesticide exceeding federal drinking water standards. While much additional research needs to be done, pesticides have been found in groundwater in each of the Great Lakes states and Ontario. Studies in Illinois and Minnesota confirm that groundwater is most susceptible to contamination where chemical use is highest and the water table is shallowest.

24. How do agricultural chemicals find their way to groundwater?

As with all potential groundwater contaminants, agricultural chemicals that reach the ground surface and are not removed by the soil or plant roots may eventually seep into the water table. The most common causes of groundwater contamination by agricultural pesticides and fertilizers include: 1) spills or leaks during handling and storage by either the supplier or farmer; 2) excessive or ill-timed application; and 3) disposal of rinsewater and excess pesticides on the ground surface.

25. What are the human health effects of pesticides in our groundwater?

The recent discovery of widespread pesticide contamination of drinking well water has caused significant concern. The health effects of pesticides are addressed in terms of "acute toxicity" (effects from immediate, short-term exposure), and "chronic toxicity" (effects from long-term exposure). While the level of pesticide concentrations found in well water is generally well below that which might cause acute health effects such as burns, nausea, or vomiting, there is concern over potential chronic health effects. Potential chronic effects include increased cancer, birth defects, genetic mutations, and a host of other impacts such as damage to the kidneys or central nervous system. Unfortunately, due to the difficulty of measuring the effects of chronic or prolonged exposure to very low levels, the U.S. EPA has not yet established drinking water standards for most pesticides.

Despite the scientific uncertainty, it is clear that with the U.S. annually producing approximately 1.1 billion pounds of 50,000 different pesticide products, there is a need for groundwater protection measures to keep

Fertilizers and pesticides can contribute to groundwater contamination.
Source: *Groundwater Education in Michigan* – Michigan State University

pesticides out of our water supplies. Some pesticides have potential health effects even in very low concentrations. For example, the insecticide aldicarb, one of the most common pesticides found in groundwater, has a drinking water standard of 7 parts per billion. This means that a single pound of aldicarb could contaminate the entire annual water supply of more than 2000 people.

26. What are the effects of livestock operations and feedlots on groundwater?

Confined animals in high density livestock operations and feedlots creates a waste disposal problem. If animal waste is improperly managed or stored, high levels of bacteria, viruses, and nitrates can seep into the groundwater. Wastes can reach groundwater from improperly sited storage locations, poorly designed surface impoundments, excessive or ill-timed land application, or uncontrolled drainage from feedlots. Proper animal waste management includes storage with adequate isolation distance between the waste and the water table and control of drainage from the feedlot.

27. How can agricultural contamination of groundwater be prevented?

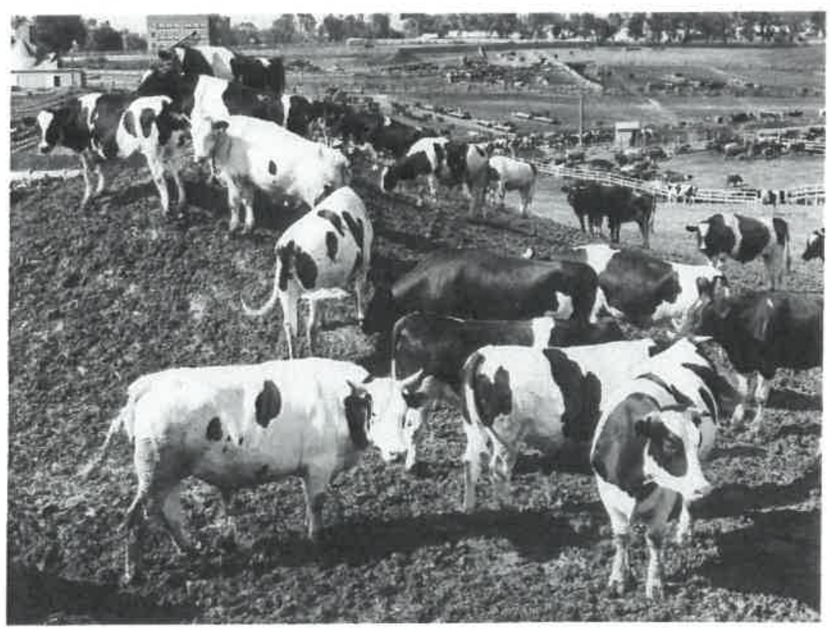
There are many ways that agricultural contamination of groundwater can be prevented. Foremost are preventive farm practices or best management practices (BMPs) that can be encouraged through education and assistance programs. The use of techniques such as Integrated Pest Management (IPM), soil conservation, and proper application, storage, and handling of fertilizers and pesticides can significantly reduce the potential for groundwater contamination. Many of these farm management approaches will improve health and environmental quality without sacrificing high crop yields and quality, and also improve profitability by reducing costs for chemical inputs. Chapter 5 discusses education programs targeting agriculture in the region.

In addition to continued research efforts such as defining groundwater recharge areas and aquifer vulnerability, state agencies should take the lead in promoting drinking water standards and rules for screening, storage, transportation and use of fertilizers and pesticides.

Another regulatory option for protecting groundwater from agricultural activities is through local zoning. Working with departments of agriculture and other state agencies, zoning permits can be conditioned on compliance with accepted state practices. One advantage of this approach is that it encourages uniform and consistent standards across local jurisdictions within a state.

28. What is integrated pest management (IPM)?

Integrated Pest Management, commonly called IPM, seeks to reduce pesticide use while maintaining high quality crops and protecting human health and the environment. The technique combines the use of beneficial organisms such as predators, parasites, and pathogens with specially targeted pesticide application to significantly reduce overall chemical use while maintain-



Large-scale dairy cattle and operations produce great amounts of waste that can contaminate groundwater.
Source: Soil and Water Conservation Society

ing crop yields. In New York, for example, onion farmers using IPM techniques succeeded in reducing their insecticide use by 54 percent, saving $24 per acre in insecticide costs, and maintaining the quality of their harvest.

Studies suggest that by adopting currently available IPM techniques, farmers could reduce their pesticide use by 40 to 50 percent in the next five years and 70 to 80 percent in the next ten years without sacrificing their crop yield or profits. This is of great significance because reducing pesticide use means reducing the threat of groundwater contamination.

29. What are the impacts of oil and gas production on groundwater?

Oil and gas production pose a variety of threats to groundwater. Two issues are of primary concern: 1) proper disposal and storage of the hazardous liquid waste by-products from the production process; and 2) the potential for the production well itself to act as a channel for rapid contaminant movement. The greatest single threat to groundwater comes from saline wastewater called brine. Improper storage and transport of brine, which may be contaminated with chlorine, hazardous organic compounds, or heavy metals, is the largest contributor to groundwater contamination. Ohio alone is estimated to produce at least 40,000 to 50,000 barrels of brine per day while Michigan has 439 verified sites of brine-related environmental contamination associated with oil and gas production.

Legal methods for brine disposal include deep-well injection and road spreading for ice and dust control. In 1991, Ontario disposed of 10 million barrels of oil field brine in 37 injection wells and spread an unknown volume on roads. Too often, brine and other oil field wastes are improperly handled or illegally dumped and cause groundwater contamination. With thousands of wells in production, tens of thousands of abandoned wells and very limited regulatory staff and funding, many observers make a strong case for increasing government oversight of oil and gas producers.

30. How does mining affect groundwater?

Major mining operations in the Great Lakes region include the extraction of coal, iron ore, and sand and gravel. Coal and iron ore mining may contaminate groundwater by leaving acidic and/or toxic materials exposed to surface water and weathering. Sulfates, iron, manganese, and dissolved solids released by mining can be picked up by water and leached into the groundwater. While current mining operations in the region are well regulated to ensure minimal environmental degradation, abandoned mine sites pose the greatest threat to groundwater. The eastern half of Ohio alone has 400,000 acres of abandoned mine lands that pose a continuing threat to groundwater. Through the federally-funded Abandoned Mine Lands program, many sites are being reclaimed but it will take many years to complete this work. In the interim, many of these excavated sites, having had their filtering capacity reduced by loss of soil layers, represent avenues for rapid infiltration of contaminants to the groundwater.

E. URBAN AND RURAL NONPOINT SOURCE POLLUTION

We generally consider the source of water pollution as being large, centralized or "point source" polluters such as industries and sewage treatment plants. These polluters have a clearly identifiable source such as a waste discharge pipe. The largest overall contributor to groundwater contamination today, however, comes from what we call nonpoint source pollution; contaminants originate from numerous, small sources scattered over our rural and urban landscapes.

Nonpoint source contamination sources includes urban runoff, septic systems, fertilizer and pesticide application, salts or other deicing compounds spread over roadways, and atmospheric fallout such as acid rain. Because these sources are so widespread and include a great diversity of contaminant types, they are particularly difficult to monitor and control. The potential for groundwater contamination from nonpoint sources depends on the quantity, type, and toxicity of the contaminants and the ease with which they can infiltrate down to groundwater.

31. What is urban runoff and how does it affect groundwater?

Urban runoff is water that flows overland across impermeable urban surfaces such as roadways, parking lots, and rooftops. Acting as a solvent, this runoff carries with it bacteria, nitrates, lead, road salt, hydrocarbons, gas and oil, pesticides, and many other potential contaminants. While much of this runoff is directed by sewers to water treatment plants or directly into surface water bodies, some may eventually infiltrate down to groundwater.

Virtually anything left exposed to rainfall and runoff in the urban landscape has the potential to contaminate runoff and thereby groundwater. Common examples of such urban contaminant sources include spills, unregulated dumping, auto emissions, application of road salt, abandoned commercial or industrial sites, and homeowner or municipal pesticide and fertilizer application.

32. How can we prevent contaminated urban runoff from polluting groundwater?

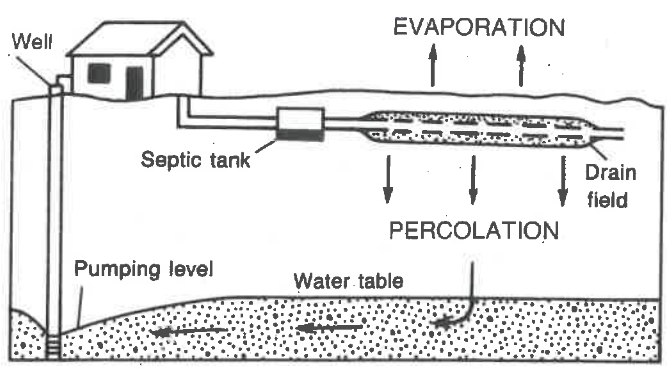
Through public education and anti-dumping codes we can help to eliminate many of the miscellaneous contaminant sources which litter our roadways and other urban landscapes and contaminate urban runoff. Communities and municipalities can help minimize the contamination potential of urban runoff by promoting street sweeping, household hazardous waste collection, used oil recycling, careful regulation of roadway salting, and cleanup of abandoned commercial and industrial sites. Additional preventive measures include controlling erosion from construction sites and directing street runoff to vegetated collection basins. It should be noted that municipal water treatment facilities, while treating human wastes, allow synthetic organic chemicals and petroleum products to pass untreated into surface water.

33. What are septic systems and how do they affect groundwater?

Septic systems are sewage treatment systems designed for low density residential or rural areas. The system consists of two parts: a septic tank, which holds solid material, and a drainage field, which allows liquids leaving the septic tank to drain into the soil where microorganisms facilitate decomposition of the waste stream before infiltrating into groundwater (see Figure 3-6). Household chemicals such as paints, pesticides, and oil may pass right through the drain field killing microorganisms and contaminating groundwater. In addition, soils in the drainfield can only handle a limited volume of waste material depending on a variety of factors including soil permeability and distance to groundwater.

Thus, septic systems can easily cause groundwater contamination when they are too densely situated or improperly designed, maintained, or used. Groundwater contaminants originating from septic systems include, bacteria, viruses, nitrates, and household chemicals such as cleaners and paint thinners. Public education which promotes adequate inspection and cleaning, and highlights the need to refrain from disposing of household chemicals in the septic system, hold the key to preventing contamination. Public agencies need to ensure proper installation of septic systems through zoning requirements and local septic system codes.

Figure 3-6
Septic effluent percolating to groundwater

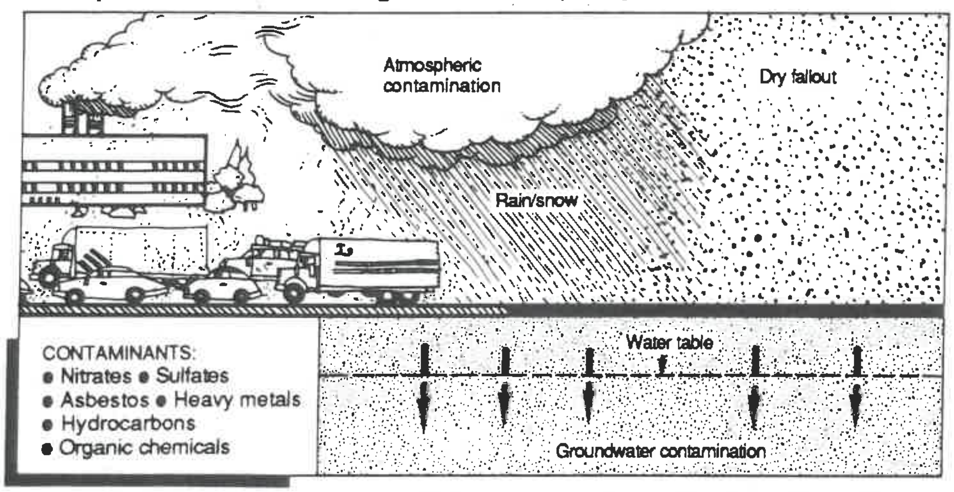


Source: U.S. Geological Survey

34. What is atmospheric deposition and how does it affect groundwater?

Atmospheric deposition is pollution that is carried in the air and comes back down to earth either through dry fallout or through rain and snow. Atmospheric deposition originates from industrial emissions, such as organic chemical manufacturers and coal/oil fired power plants, as well as neighborhood emissions, such as from motor vehicles, gas stations, dry cleaners, and woodstoves. Contaminants such as nitrates, heavy metals, hydrocarbons, organic chemicals, and asbestos can become airborne and be deposited far from their original source and, through infiltration, contaminate groundwater (see Figure 3-7).

Figure 3-7
Atmospheric influences on groundwater quality



Source: *Groundwater Contamination*, Raymond, Lyle S., Jr., New York State Water Resources Institute, Center for Environmental Research, Cornell University, 1988

Atmospheric contamination has proven to be a "major pathway for contamination of the Great Lakes ecosystem" (International Joint Commission, 1987). While as much as 90 percent of some toxic substances entering the Great Lakes comes from atmospheric deposition, it is not known exactly how much it contributes to contamination of groundwater. Nevertheless, the enormity of the problem and threat to public health call for continued prevention efforts. More research is needed to clarify the probable but unproven link between groundwater contamination and deposition of airborne contaminants.

F. GROUNDWATER WELLS

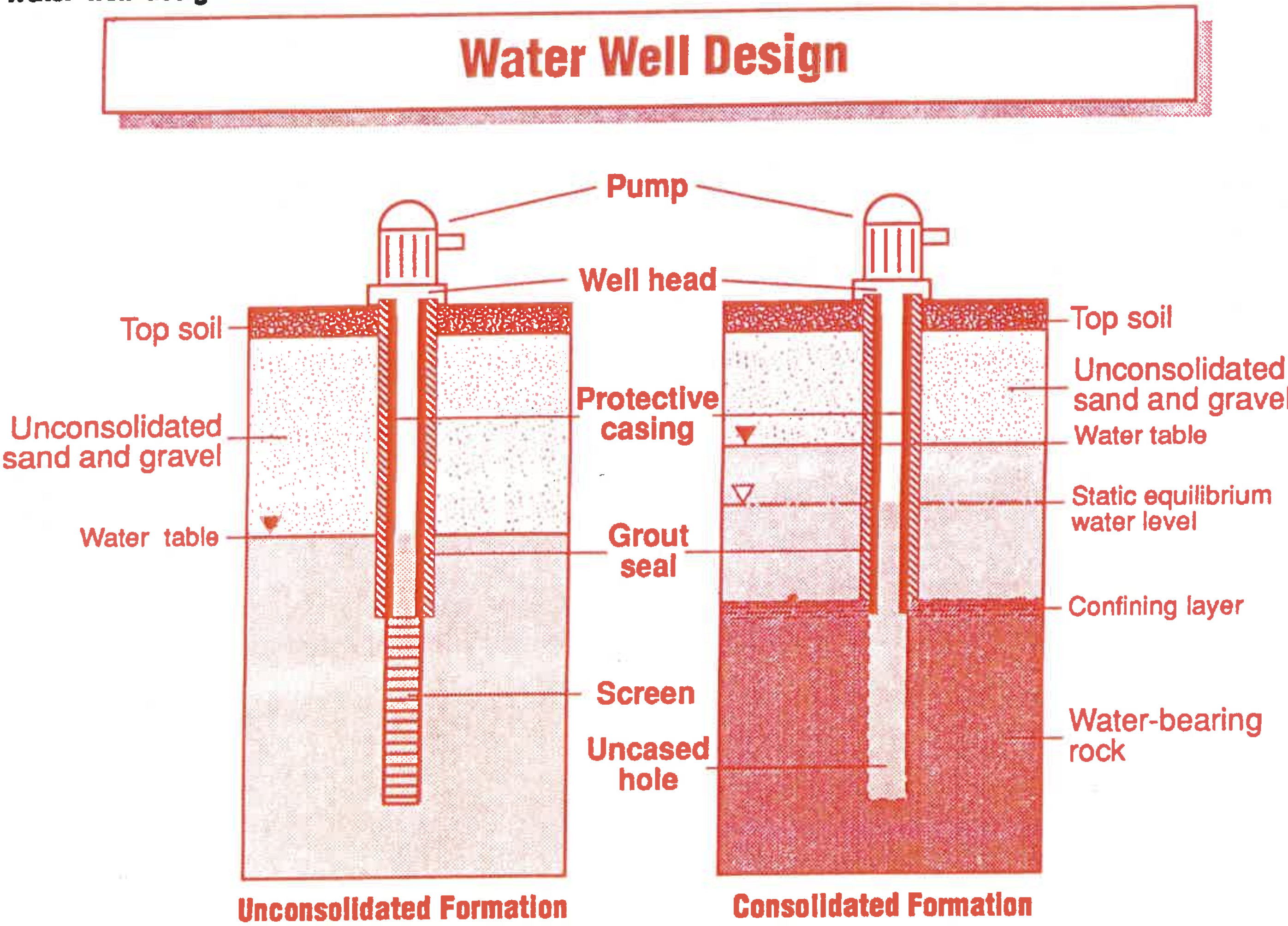
Groundwater wells represent both an opportunity and a risk. Developed with forethought as part of a community's overall water supply planning efforts, groundwater wells can represent a dependable source of clean water and an opportunity for economic and community development. On the other hand, poor planning when developing groundwater wells can cause irrevocable depletion and/or contamination of the resource, and create a detriment to economic development and public and environmental health.

35. How is a groundwater well conructed and how does it impact local groundwater resoures?

Depending on the intended use of a well (e.g., private residence, municipal water supply, waste-injection, or groundwater monitoring), construction practices may differ. Most modern wells are constructed with a vertical pipe, or casing, placed in a borehole made by a drill rig (see Figure 3-8). The space (annular space) between the casing and the borehole is sealed with clay or cement to block water from flowing vertically along the outside of the well. In sand and gravel aquifers, water enters the well through a well screen adjacent to the aquifer zone in which small openings permit the entrance of water but not fine-grained materials. Wells in bedrock aquifers commonly have an "open- hole" construction with no screen because the water is obtained from cracks and fissures with few fine particles. Water is drawn to the surface using a pump placed in the well which may be anywhere from ten to hundreds of feet deep.

Proper well construction can prevent the potential for wells to act as channels for con-

Figure 3-8
Water well design



Source: *Groundwater Education in Michigan*, Michigan State University

taminants to enter aquifers. For example, a contaminant on the ground surface that would otherwise be contained by the soil and rock layers, could move quickly along the outside of an improperly sealed well causing serious contamination to an aquifer. To prevent such contamination, licensed well contractors are required to follow certain design specifications and obey regulatory permitting and registration procedures. Contact your county health department or appropriate state/provincial agency to determine what regulations govern well construction in your locality. At a minimum, these requirements should provide for a sanitary surface seal (commonly impermeable clay) that prevents water from infiltrating next to the well.

36. How do abandoned wells affect groundwater?

Abandoned wells create potential problems for public safety and groundwater contamination and should be properly sealed. Like active wells, abandoned wells have the potential to act as a channel for rapid contaminant movement. In effect, abandoned wells make local aquifers more vulnerable to contamination. Abandoned wells are of particular concern because of the many unknowns associated with them; their numbers, location, depth, and well construction information (which is helpful for proper sealing), are often only discovered after some accident or contamination incident has occurred. In addition, the common use of old wells as ready-made waste disposal sites and their generally unsealed condition due to corrosion or archaic construction methods, make abandoned wells particularly likely sources of groundwater contamination.

Proper sealing of an abandoned well requires that they be filled with clean soil, preferably an impermeable clay or cement. The well casing should be perforated or removed down to a designated depth so that contaminants cannot move downward along the walls of the casing. Contact your county health department or appropriate state/ provincial agency to determine what regulations govern proper sealing of abandoned wells in your jurisdiction.

Headline News – 18-month Old Girl Falls in Abandoned Well

Many people may remember the media-blitz surrounding the saga of 18-month-old Jessica McClure of Midland, Texas, who, in October 1987, fell into an open well and remained trapped for 58 hours. Fortunately Jessica was rescued. We can all recognize the immediate threat the abandoned well posed to Jessica's life. Less widely recognized is the long-term threat that these abandoned wells pose for groundwater contamination.

37. What is groundwater yield or "safe yield"?

Groundwater yield is defined as the maximum amount of water that can be withdrawn without causing an unacceptable lowering of the water table. The concept is applied at various scales including well yield, aquifer yield, and basin yield. The terms refer to the maximum amount of water that can be withdrawn without causing unacceptable lowering of the water in the well, the aquifer, or the basin respectively. This same concept is expressed by the term "safe yield."

38. Can groundwater resources be overused?

Yes. Groundwater overdraft or "mining" is an unsustainable rate of groundwater withdrawal causing permanent depletion of the resource. Overdraft may also be defined as any groundwater withdrawal in excess of safe yield. This occurs when the amount of water extracted exceeds the amount of water naturally recharged into the aquifer over a number of years. Although short-term depletion of aquifer storage may occur during drought years, aquifers will normally recover following a series of wet years.

In addition to destroying an aquifer's potential for sustainable yield, groundwater overdraft can have other serious impacts including, land subsidence, increased pumping costs, reduction in local surface water flows, destruction of wetlands or other critical habitats, and groundwater contamination. In the Great Lakes Basin, major instances of groundwater overdraft have occurred in Chicago, Milwaukee, Green Bay, and Lansing. As a result, many privately owned wells have either run dry or experienced increased pumping costs.

39. How can a local government or private resident determine the potential for developing their groundwater resources?

The quantity of water available from a well ultimately depends on the thickness of the aquifer, the aquifer's characteristics (e.g., permeability), and the type of well. In general, thick, highly permeable aquifers provide the largest well yields. Maps of topography, surface geology, bedrock, and depth to the water table, if available, will provide useful information. However, a thorough understanding of the groundwater system may require a detailed local investigation. Groundwater resource evaluation techniques include both surface and subsurface investigations using geophysical techniques, groundwater monitoring, and computer aided modeling.

Well and aquifer data is more readily available in the region's more densely populated areas. Although there may not be a map delineating potential well yields, local well contractors and the yields of neighboring wells can provide a good indication of an aquifer's potential yield. Groundwater development should also carefully consider human factors such as uphill land uses and the intensity and proximity of current and future groundwater uses.

Because most groundwater development is performed with incomplete knowledge of the groundwater system, planning must continue after wells are installed. Information gathered during the drilling and pumping of new wells, in addition to the effects on nearby wells or surface water should be used to refine understanding of the system and lead to appropriate adjustments of pumping rates.

Finally, sound groundwater development requires wells that are properly constructed and located. It is advisable to hire a well drilling contractor licensed with the state or province to ensure that the well is installed according to well code specifications. For questions of technical complexity or for greater assurance about groundwater development issues, professional help should be sought.

40. Is water conservation important in water supply planning?

Yes. Water conservation reduces the total quantity of water withdrawn from an aquifer and reduces a community's total demand for water. In addition, water conservation considerably reduces home energy costs for heating water; reduces water and sewer bills; and may reduce the need to expand expensive water supply and sewage systems. Conservation also contributes to higher streamflow, which benefits fish and wildlife habitat, water quality, power generation, agriculture, transportation and recreation.

There are many steps that local governments and homeowners can take to conserve water. Some steps, like water efficient plumbing, require structural changes. However, creative and conservation-minded water use can also save a lot of needless waste and help to protect groundwater. Water conservation educational materials are available from the Great Lakes state and provincial governments. Chapter 7 provides agency contacts in your jurisdiction.

Chapter 4

GROUNDWATER PROTECTION IN THE GREAT LAKES REGION

This chapter explores the role of groundwater protection efforts within the framework of federal, state, and county programs. Options for local government groundwater protection initiatives are introduced and future challenges and opportunities are examined.

A. INTRODUCTION TO GROUNDWATER PROTECTION IN THE GREAT LAKES

1. Why Groundwater Protection?

Once groundwater is contaminated it may remain that way for hundreds or even thousands of years. Although it is sometimes possible to clean up contaminated groundwater, technical and legal difficulties combined with an exorbitant cost, make groundwater cleanup prohibitive.

Drilling a monitor well at a landfill.
Source: Wisconsin Department of Natural Resources

Technical uncertainties in groundwater remediation and cleanup programs include: direction and rate of contaminant movement; determination of extent and source(s) of the contamination; and feasibility of technical approaches. Because groundwater moves so slowly and contaminants are partially retained by the aquifer materials, contaminated groundwater cannot generally be returned to its original quality.

In light of these technical, time, and economic considerations, prevention of groundwater contamination is clearly the most rational option for groundwater protection and management.

2. Why does the Great Lakes region need intergovernmental cooperation to promote groundwater protection?

Unlike political boundaries, groundwater resources do not have arbitrary limits. The Great Lakes form a single hydrologic or water-dependent system in which actions taken by one jurisdiction may impact neighboring or even distant areas. Although some of the region's productive aquifers underlie a limited geographic area, they may be contaminated by surface waters of distant origin or themselves create distant impacts by discharging contaminants into wetlands, streams, rivers, and lakes. Thus a localized response to groundwater problems which are regional in scope is at best a piecemeal and costly approach to protecting the resource. This is especially true for developing basic research programs which, due to their expense and technical complexity, are best undertaken with regional cooperation.

There is no comprehensive legislative mandate to protect groundwater or coordinate the many, fragmented levels of regulatory responsibility. Intergovernmental cooperation toward groundwater protection is necessary to develop coordinated policies and programs which can effectively respond to the Great Lakes region's complex, regional groundwater problems.

3. Is there a regional groundwater management program for the Great Lakes?

No. There is no one program which focuses on groundwater protection in the Great Lakes region. Historically, binational-national efforts to address water quality concerns have emphasized the quality of Great Lakes surface waters only. It is only recently that groundwater's importance within the Basin's hydrologic cycle and in particular its potential as a contaminant pathway or avenue for contaminants to enter the Great Lakes has been fully recognized. Appendix A outlines major regional initiatives for water resources protection.

4. Who is responsible for protecting groundwater resources in the Great Lakes region?

Groundwater protection is everyone's responsibility. Citizens, educators, business and industry, agriculture, and government agencies at the local, county, state, provincial and federal levels all have a unique role to play in groundwater protection. Chapter 6, *Community and Citizen Involvement: What You Can Do*, provides tips on citizen participation.

While states and provinces have the primary regulatory role, various federal agencies and statutes are concerned with the prevention, detection and cleanup of groundwater contamination. The lead federal agencies are the U.S. Environmental Protection Agency and Environment Canada. Chapter 7, *Where to Obtain Help: Groundwater Protection Information, Assistance, and Protection Programs*, outlines federal and state/provincial programs and provides contact information.

Since most groundwater contamination originates from local land use activities, prevention requires local government initiative to protect groundwater resources. Options for local groundwater protection, discussed in the next section, are just one element within a framework of federal, state, county and local programs (see Table 4-1).

Table 4-1
Regulations with Groundwater Protection Benefits
Examples from State, County, and Local Government

State Agencies
- Agricultural chemical storage regulations
- Underground storage tank regulations
- Flammable and combustible storage regulations
- Public drinking water supply regulations
- Planning reviews for on-site septic systems and wells
- Regulations for construction and abandonment of drinking water wells
- Periodic water quality monitoring
- Groundwater discharge regulations
- Hazardous waste storage, spill prevention, and transport regulations
- Oil and gas well drilling regulations
- Spill reporting, environmental response, and cleanup regulations

County Agencies
- Permitting for water well construction
- Permitting for septic systems
- Compliance inspections for groundwater discharge, solid waste and community water supply facilities
- Planning reviews for on-site septic systems and water supplies

Local Agencies
- Zoning ordinances (site plan review, special permit review)
- Special purpose ordinances for groundwater protection (e.g., hazardous chemical ordinances)
- Building permits and occupancy inspections
- Fire safety inspections (storage of flammable and combustible materials)

Adapted from *Community Planning & Zoning for Groundwater Protection in Michigan: A Guidebook for Local Officials*, Michigan DNR, 1990.

5. Do all the Great Lakes states have groundwater protection programs?

Yes. All of the Great Lakes states have groundwater protection programs. Historically, the states have performed limited groundwater management functions such as providing adequate public water supplies. While some states have been working on groundwater protection since the early 1970s, it was not until the U.S. EPA developed the National Groundwater Protection Strategy in 1984, that the federal government began coordinating its efforts to promote comprehensive state groundwater protection programs. Currently, programs vary considerably from state to state; often consisting of a patchwork of federal, state, or local efforts. With the assistance of the EPA, however, state programs have developed significantly in the last few years and several states have either passed, or are developing, strong groundwater protection legislation.

For each state, an overall policy and planning framework is provided by the state's "groundwater protection strategy." These strategies address topics such as public education, groundwater data management, legislative and regulatory developments, resource assessment, groundwater classification, point and nonpoint source contaminant controls. The state strategies were developed in response to a critical lack of coordination among numerous state regulations and agencies, none of which had a mandate specifically aimed at groundwater protection.

Table 4-1
Regulations with Groundwater Protection Benefits
Examples from State, County, and Local Government

State Agencies
- Agricultural chemical storage regulations
- Underground storage tank regulations
- Flammable and combustible storage regulations
- Public drinking water supply regulations
- Planning reviews for on-site septic systems and wells
- Regulations for construction and abandonment of drinking water wells
- Periodic water quality monitoring
- Groundwater discharge regulations
- Hazardous waste storage, spill prevention, and transport regulations
- Oil and gas well drilling regulations
- Spill reporting, environmental response, and cleanup regulations

County Agencies
- Permitting for water well construction
- Permitting for septic systems
- Compliance inspections for groundwater discharge, solid waste and community water supply facilities
- Planning reviews for on-site septic systems and water supplies

Local Agencies
- Zoning ordinances (site plan review, special permit review)
- Special purpose ordinances for groundwater protection (e.g., hazardous chemical ordinances)
- Building permits and occupancy inspections
- Fire safety inspections (storage of flammable and combustible materials)

Adapted from *Community Planning & Zoning for Groundwater Protection in Michigan: A Guidebook for Local Officials*, Michigan DNR, 1990.

5. Do all the Great Lakes states have groundwater protection programs?

Yes. All of the Great Lakes states have groundwater protection programs. Historically, the states have performed limited groundwater management functions such as providing adequate public water supplies. While some states have been working on groundwater protection since the early 1970s, it was not until the U.S. EPA developed the National Groundwater Protection Strategy in 1984, that the federal government began coordinating its efforts to promote comprehensive state groundwater protection programs. Currently, programs vary considerably from state to state; often consisting of a patchwork of federal, state, or local efforts. With the assistance of the EPA, however, state programs have developed significantly in the last few years and several states have either passed, or are developing, strong groundwater protection legislation.

For each state, an overall policy and planning framework is provided by the state's "groundwater protection strategy." These strategies address topics such as public education, groundwater data management, legislative and regulatory developments, resource assessment, groundwater classification, point and nonpoint source contaminant controls. The state strategies were developed in response to a critical lack of coordination among numerous state regulations and agencies, none of which had a mandate specifically aimed at groundwater protection.

6. **What system of water rights/water laws is used in the Great Lakes states and provinces?**

The water rights systems in all Great Lakes states and provinces follow the same general doctrine: the riparian doctrine of reasonable use. This doctrine provides owners of land adjacent to, or containing, surface or groundwater the right to make reasonable use of that water as long as it relates to some beneficial activity on the adjacent or overlying land. Within the legal interpretation of the riparian doctrine there is a fine distinction between surface water and groundwater.

In the water-rich Great Lakes Basin, however, rights to groundwater have not historically been a common legal consideration. In areas with major water users, such as industry or municipalities, local wells are increasingly being affected by overdraft or depletion of the resource. Ultimately, the concern is economic, since continued overdraft can necessitate costly deepening or modification of local wells and pump systems.

Illinois, Indiana, Minnesota, New York, Ohio, Wisconsin and Ontario require large water users to register or obtain water withdrawal permits. Illinois, Indiana, and Ontario have well interference complaint programs in which well owners can petition the state water authority to decrease pumpage from the offending high-capacity well. Of the Great Lakes states and provinces, only Minnesota has a formal system defining water use priorities. In practice, domestic use of water generally has the highest priority in all Great Lakes jurisdictions; in addition, public water suppliers serving public needs often have priority over individual users.

B. LOCAL GROUNDWATER PROTECTION INITIATIVES

7. **Why should groundwater protection be the concern of local government?**

Assuring a high quality natural resource base including groundwater is essential for long-term, sustainable economic development in local communities. While state, provincial and county governments address priority natural resource concerns, their regulatory efforts do not provide comprehensive protection for groundwater resources.

Local governments have both the responsibility and the authority to protect their community's groundwater resources. Two extremely important tools for local governments' groundwater protection efforts are land use zoning and local ordinances. One important way these tools may be used is to safeguard community groundwater supplies from high risk businesses which are not regulated by state and federal programs. Table 4-2 provides examples of some of the so-called "light industries" that pose a potential threat to local groundwater resources. Land use planning and ordinances can encourage these businesses to safely manage their wastes.

8. **How can groundwater protection be incorporated into the local planning process?**

Most threats to groundwater come from local land uses which are planned, regulated, and supported by local governments. Implementing local groundwater protection measures, such as the well-head protection program discussed in Table 4-3, begins by conducting an inventory of groundwater uses and vulnerability and identifying the contamination potential of current and projected land use activities. Successful community-based groundwater planning empowers local decision makers to take into consideration important factors such as:

- The value of groundwater for the community's future;
- The interrelation of groundwater protection with land use policies, regulations, and decisions on infrastructure investment;
- The potential for improved intergovernmental cooperation at all levels and across agency jurisdictions such as public health and water resource protection.

Table 4-2
Examples of "Light Industry" — An Overlooked Source of Groundwater Contamination

A 1990 report by the U.S. EPA highlighted the need to carefully manage "light industry," or industrial, commercial, and retail businesses that are not generally regulated by federal hazardous materials regulations. Those "light industries" identified as having the highest potential for groundwater contamination and some of the wastes generated include:

Automotive Service and Repair Shops
- Waste oil, lubricants, and transmission fluids
- Spent solvents, cleaning solutions and sludge
- Spilled lead battery acid

Metal Finishing and Fabricating Facilities
- Heavy metal wastewater sludges
- Spent plating baths
- Degreasing solvents

Scrap and Junk Yards
- Used oil, gasoline, and antifreeze

Laundry and Dry Cleaning Establishments
- Degreasers and cleaning solvents

Wood Preservers and Refinishers
- Treatment chemicals (e.g., pentachlorophenol, creosote, chromated copper arsenic)
- Stripping solutions (e.g., acetone, perchloroethylene, toluene)

Road De-icing Operations
- De-icing materials; improper storage or application

To reduce or eliminate the amount of waste fluids being generated and disposed of, the U.S. EPA promotes programs for source reduction, recycling and resource recovery, and wastewater treatment. Promoting these waste reduction options is good business; it can reduce costs help to safeguard community groundwater resources.

Adapted from *Shallow Injection Wells and How They Affect Drinking Water*, a pamphlet by U.S. EPA Region IX, 1990.

Armed with this information, and an understanding of their local administrative and financial capabilities, communities can take control of their own futures by adopting policies and regulations best suited to their particular situation. Highlighted in Table 4-4 are some important management tools for local groundwater protection efforts, including, land use planning options, best management practices, ideas for waste reduction and prevention, and themes for public education programs.

9. Where should a local official go for information on current groundwater issues and management options?

While there is a wealth of groundwater data, it is often not in sufficient detail or appropriate form to provide maximum benefit to local officials. It is essential that local officials become informed about what does exist and to build working relationships with state, county and other local government officials. Sharing accumulated experience and resources offers an essential first step toward understanding the groundwater data and policy options your community needs to consider.

In addition, developing good intergovernmental communication is the key to coordination and regulatory consistency. For agency contacts in your state or province, their responsibilities and resources, see Section C in Chapter 7, "State and Provincial Programs."

10. What sources of funds are available for local governments' groundwater protection efforts?

The four basic funding sources are: community revenues from dedicated taxes and fees; private expenditures; intergovernmental grants, and bonds or bank loans. Many local communities in the Great Lakes region have received grants for well-head protection programs and other local groundwater initiatives. The lead agency for your state or province is listed in Chapter 7; contact them for more information.

C. GROUNDWATER PROTECTION: A LOOK TO THE FUTURE

11. What trends are likely to occur in groundwater protection?

Many people are asking themselves what is needed to make the 1990s and beyond an era of groundwater protection and stewardship. While there are some clear trends and needs,

Table 4-3
Well-head Protection

Well-head protection is a planning and management approach for preventing contamination of public water supply wells which use groundwater. Local communities are strongly encouraged to develop a wellhead protection program to prevent their wells from becoming contaminated. Under the U.S. federal Safe Drinking Water Act, all wellhead protection programs are required to:

- Specify the roles of state and local governments and public water suppliers;
- Delineate wellhead protection areas for each well or well field;
- Identify sources of contaminants within each well-head protection area;
- Develop management approaches to protect the water supply within well-head protection areas from those contaminants;
- Develop contingency plans for each public water supply system in the event of well or well field contamination;
- Locate new wells properly to minimize potential contamination;
- Ensure public participation in well-head protection program development.

Adapted from *Progress in Ground-Water Protection and Restoration*, U.S. Environmental Protection Agency, February, 1990.

the complexity and inherent uncertainties associated with groundwater and the diversity of communities which it supports, means that unresolved questions and difficult decisions will always remain. Far from throwing up our hands, however, our response to these challenges is rich with opportunity.

Education

One thing is certain — pollution prevention through education is the cornerstone of any rational groundwater protection policy. Education provides communities the opportunity to make collective and private choices on issues that affect their groundwater resources. In the aftermath of groundwater contamination, many communities find themselves contending with harsh social, economic, and environmental realities which may have been avoided, had they understood the groundwater protection options available to them. A 1991 survey of local groundwater management activities in Pennsylvania revealed that next to funding needs, the most critical program element for local governments is community education. There is also a need to integrate groundwater education into the state/provincial K-12 educational objectives.

Policy

Growing out of this heightened awareness, groundwater protection policies of the 1990s will most likely emphasize local communities working in partnership with state, provincial and federal agencies. Incentives to encourage businesses and industries to engage in voluntary waste and source reduction programs are also likely to be highlighted. State, provincial and federal governments will continue to provide local jurisdictions with educational, financial, and technical assistance. Benefiting from their regional perspective, they will also need to ensure that management efforts are based on a systems perspective which recognizes the interrelationship of land and water resources. Local officials cannot afford to approach groundwater management from a piecemeal perspective that may undermine water resource issues that are inherently regional in scale.

While U.S. policy currently emphasizes the states' primacy in groundwater protection, many observers believe that national groundwater legislation may be necessary to provide states with the necessary momentum and consistency nationwide. Because groundwater quality is not specifically included in national water quality protection legislation, many states have developed their own regulations; creating inconsistencies across single hydrologic regions such as the Great Lakes Basin. Section 319 of the Water Quality Act of 1987 (PL 100-4), which amended the Clean Water Act, requires a consistent, nationwide land classification system for water pollution vulnerability, but it does not specifically address groundwater pollution.

Table 4-4
Groundwater Protection Options:
Management Tools For Local Government

Land Use Planning
- **Link to other Permits**; zoning approval is conditioned on the issuance of county, state and federal environmental permits/approvals
- **Site Plan Review**; establish groundwater protection standards as criteria for approval of site plans
- **Groundwater Protection Overlay Zoning**; (e.g., *wellhead protection zone*) this approach delineates specific geographic locations where special protective measures are added or overlaid on the basic zoning district
- **Groundwater vulnerability mapping**

Regulations
- **Hazardous Substance Control Ordinance**; these regulations can be integrated into local zoning or enacted as separate ordinances
- **Interjurisdictional, Regional, or Aquifer-wide Permit Program**; using intercounty programs or special metropolitan districts, this approach seeks a coordinated management plan among communities dependent on a single aquifer
- **Building permits and occupancy inspections**
- **Fire safety regulations**; controlling storage of flammable and combustible materials

Best Management Practices
- Groundwater monitoring plans
- Inventory of known and potential groundwater contamination sites
- Water well isolation distances for hazardous materials handling and storage
- Design standards such as secondary containment for hazardous materials handling and storage, and minimizing impervious surfaces to protect aquifer recharge
- Spill prevention and waste reduction plan
- Soil conservation measures to manage run-off and infiltration
- Source prohibitions to prohibit development or materials that threaten groundwater.

Waste Reduction and Prevention
- Environmental audits to achieve waste reduction goals through source reduction, recycling, reclamation, treatment, and reuse
- Incentive programs

Public Education Programs
- Building community support for groundwater protection efforts
- Promote safe household practices such as proper hazardous chemical use and disposal
- Household hazardous waste collection
- Water conservation

Adapted from *Community Planning & Zoning for Groundwater Protection in Michigan: A Guidebook for Local Officials*, Michigan DNR, 1990.

Technology

12. Are the groundwater resources in the region fully developed and understood?

No. Comprehensive management and protection of groundwater resources in the Great Lakes region will require much greater knowledge of the region's complex groundwater systems. Unfortunately, gathering, processing, and accessing this vital information is expensive, requiring extensive groundwater monitoring and data management programs. Much groundwater information of local and regional importance is still needed, including: location of abandoned wells, critical aquifer recharge areas, groundwater contaminant movement, aquifer characteristics and more.

As education about groundwater and awareness of groundwater's importance to society increase, so too will our understanding of groundwater resources. More detailed under

New Steam Injection Method Developed to Clean Up Deep Toxic Spills

In a technique modified from one used by oil companies to extract heavy crude oil, researchers have patented a new way to clean underground chemical spills using injection of high-pressure steam. Injected through perforated steel pipe at about 250 degrees Fahrenheit, the steam is reported to be nearly 100 percent effective in removing some of the most common liquid contaminants such as gasoline and industrial solvents. After being removed by a vacuum pump which draws the steam from an outer ring of injection pipes to a central well, it is condensed, captured and recycled. In 1990, its developers at UC-Berkeley made $22.2 million in royalties and patent license fees from its application at military installations and fuel spills around the nation. The work is part of a national cleanup of contaminated groundwater and soil that could cost the nation hundreds of billions of dollars in coming years.

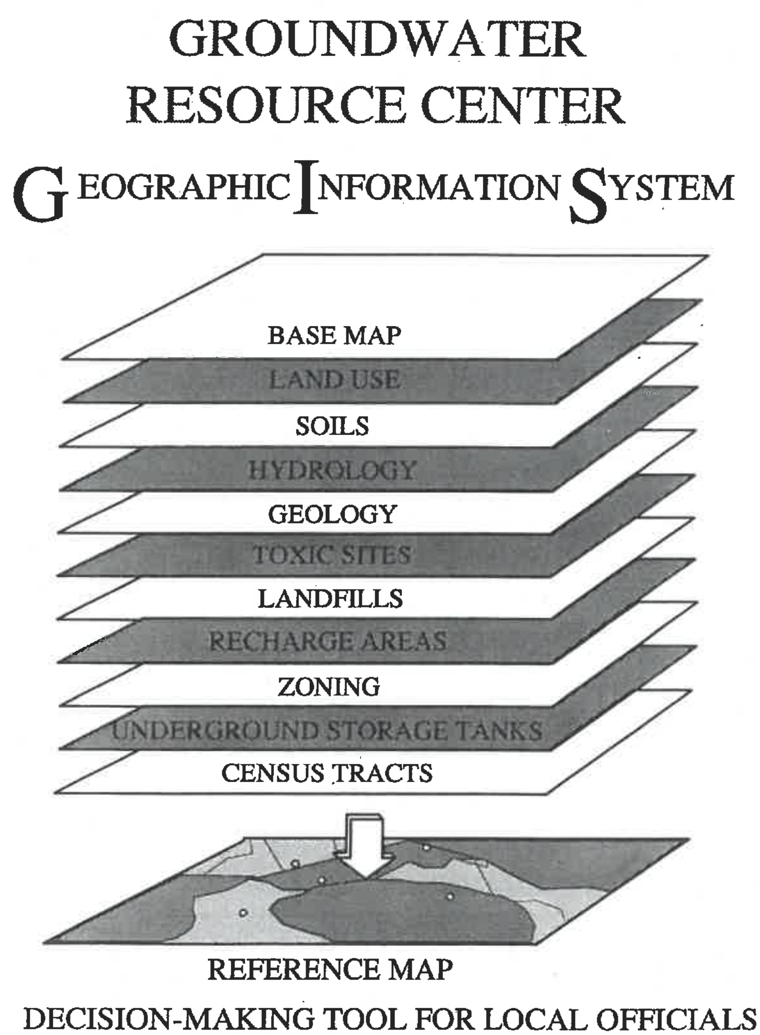
standing of groundwater systems will also help to ensure our continued development and dependence on groundwater.

13. What is a Geographic Information System (GIS)?

A geographic information system (GIS) is a computer system which combines a large amount of geographically referenced data and displays it visually as a map. A new and rapidly evolving technology, GIS applications are increasingly important for groundwater protection efforts because they allow a large amount of technical information to be synthesized for practical use and easy understanding. Figure 4-1 illustrates how the Groundwater Resource Center of the Tri-County Regional Planning Commission in Lansing, Michigan, is using GIS technology to combine many "layers" of information into a single reference map that can then be used by local officials as a tool for decision making and groundwater protection.

Application of GIS may help state agencies implement groundwater protection planning programs and provide maps containing different groundwater data layers to local governments. The U.S. EPA has developed a promising GIS application for groundwater protection called DRASTIC. The DRASTIC model analyzes hydro geologic and land use data to map groundwater vulnerability and hazards posed by land use activities.

Figure 4-1
Geographic Information System



Source: Tri-County Regional Planning Commission

Chapter 5

OPPORTUNITIES FOR GROUNDWATER EDUCATION IN THE GREAT LAKES REGION

This chapter outlines the groundwater education opportunities in the Great Lakes region for the following constituencies:

A) Classroom Teachers;

B) Local Government Officials;

C) Business and Industry;

D) the Agricultural Community; and

E) the General Public.

After a general introduction to groundwater education in the Great Lakes region, each of the five constituencies will be discussed in terms of their educational needs and program opportunities. The region's exemplary groundwater education programs will be discussed briefly.

The reader should refer to Chapter 8, "Available Resources", for a jurisdiction by jurisdiction listing of groundwater educational materials and Chapter 7, "Where to Obtain Help," for appropriate agency contacts at the local, state/provincial, and federal levels.

1. Groundwater education in the Great Lakes region is taking off! Why?

Education about groundwater is increasing rapidly because protection of this vital resource is an extremely important community issue. While concern over clean rivers and lakes has received much attention, groundwater issues have for too long remained "out of sight" must not remain "out of mind."

Although groundwater issues can seem complex, groundwater is very much a community issue. Preventing groundwater pollution depends on an informed and active citizenry. Therefore, groundwater protection efforts, like many other environmental programs, have realized the benefit of public education and participation.

As discussed in Chapter 1, groundwater is an integral part of any water ecosystem; it both supplies and is supplied by surface water. Although groundwater is singled out for educational need, it cannot be well understood without consideration of the effect of human activities on the entire hydrologic system. In this light, groundwater education must be considered within the broader movement of environmental education. Since groundwater has been long neglected in school curricula, it is especially important that groundwater should be emphasized.

Examples of the increase in importance of environmental education and citizen action can be found nationally, regionally, and locally. In November 1991 the U.S. passed the National Environmental Education Act. The new law establishes as national policy the promotion and funding of environmental education for K-12 classrooms as well as higher education. In Canada, the Green Plan includes a new Great Lakes Initiative which includes environmental education for all age groups as an essential approach to environmental problem solving. Regionally, the International Joint Commission has undertaken several initiatives to promote innovative environmental education programs in the binational Great Lakes region. Their work includes promotion of Great Lakes educational material in the region's schools, teacher training for environmental education, and policy recommendations under the Great Lakes Water Quality Agreement that the U.S. and Canada pursue environmental education to "ensure that current and future generations are aware of and understand the importance of a healthy Great Lakes-St. Lawrence Basin Ecosystem."

2. What kind of groundwater education programs exist in the Great Lakes states and provinces?

There are a diversity of groundwater education programs in the Great Lakes states and provinces targeting all parts of the community. Illinois has mandated (but not funded) groundwater education programs through the Illinois Groundwater Protection Act, while Pennsylvania, Minnesota, New York, Ohio and Wisconsin incorporate groundwater concepts under general environmental education requirements of the state department of education. Michigan, on the other hand, relies on private collaborative initiatives such as the Groundwater Education in Michigan (GEM) program. Information about GEM is included in the academic and non-governmental institutions section of Chapter 7.

A. FOR K-12 CLASSROOM TEACHERS

Groundwater is a wonderful K-12 classroom topic that can be incorporated into existing subject areas including science, earth science, language arts, health, home economics, math, social studies, and environmental studies.

3. Are there classroom-ready curriculum materials for groundwater education?

Yes! Many classroom-ready curriculum materials for groundwater education are available. Chapter 8, Available Resources, provides a state-by-state listing of curriculum and other educational resource materials. One outstanding example is Wisconsin's Buried Treasure: Groundwater Study Guide by the Wisconsin Department of Natural Resources. This attractive guide facilitates its use and infusion into the existing curriculum by 1) correlating each activity's objectives with selected state educational objectives; 2) providing clear goals, background information, materials needed, procedures, demonstration ideas, discussion questions, and ideas for extension; and 3) stimulating students by using interactive demonstrations, hands-on activities, local real world examples, interdisciplinary options, field trips, guest speakers, and challenging problem-solving exercises. Other states with similar state-specific groundwater education curriculum materials include Illinois, Michigan, and Pennsylvania. It should be noted that many of these resources can be easily adapted for use elsewhere.

Many additional groundwater education resources can be found throughout the region (see Table 5-1). For information on water resources and education programs refer to the state agency contacts listed in Chapter 7, as well as county and township health and planning departments, and water companies.

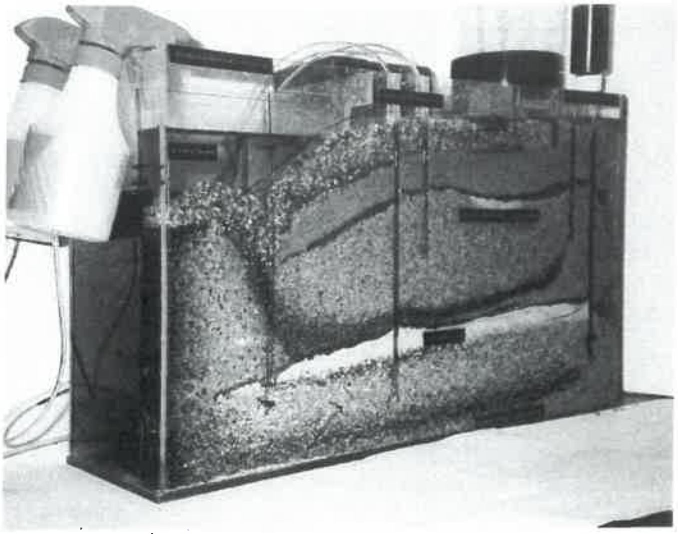
Table 5-1
Non-Governmental Organizations as Local Resources for Groundwater Education

Local non-governmental organizations may provide good educational resources — Use your telephone directory to identify local organizations such as:

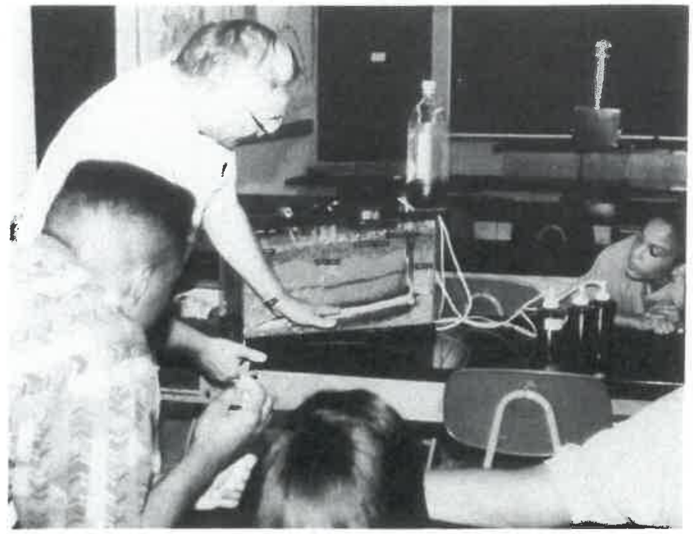
- Farm organizations
- Environmental Education Chapters
- League of Women Voters
- Sierra Club Chapters
- Trout Unlimited Chapters
- Watershed Associations
- Audubon Society Chapters
- Aquariums and Nature Centers
- Local colleges and universities
- Womens clubs

Groundwater Flow Models

One popular educational tool, shown in the photograph, is the Groundwater Flow Model. This model, which can be purchased or made, is an excellent way to clearly demonstrate and reinforce all of the important groundwater concepts. Use of the model clearly illustrates scientific processes for studying groundwater and the potential for groundwater contamination. The experience of teachers throughout the region who have used the model indicates that groundwater is a wonderful classroom subject which can open up for students a whole new way of seeing the world and understanding their place in it.



A groundwater flow model can be easily constructed with inexpensive materials. Source: GEM Regional Center, Western Michigan University



The groundwater flow model in action. Source: GEM Regional Center, Western Michigan University

Where to order:

1. Call or write R.N. Passero, to receive his paper, *A Simple, Inexpensive Ground-Water Flow Model,* which tells you how to build your own model for approximately $20, and how to teach with it. Dr. Passero's address is: GEM Regional Center, Institute of Water Sciences, Western Michigan University, Kalamazoo, MI 49008, (616) 387-5502.

2. Ground Water Model Project, College of Natural Resources, University of Wisconsin – Stevens Point, Stevens Point, WI 54481, (715) 346-4613.

3. Iowa Soil and Water Conservation Society (SCWS) Student Chapter, 3407 Agronomy Hall, Iowa State University, Ames, Iowa 50011

B. FOR LOCAL GOVERNMENT OFFICIALS

Local government officials have a very important role to play in groundwater protection. However, they must first understand the basic groundwater issues and their options and responsibilities in helping the community plan for groundwater protection. Sustainable economic development, a priority for most local governments, depends on the wise management of vulnerable natural resources such as groundwater. To manage groundwater, local officials must learn about their legal authority to protect the resource through such measures as: defining groundwater vulnerability, land use planning, well head protection, best management practices, waste reduction and prevention, and public involvement.

4. Where is useful information available for local groundwater protection efforts?

Many of the state agencies listed in Chapter 7 can provide local government officials with important information about the state's groundwater protection legislation/programs as well as guide books and fact sheets for describing the available options for local groundwater protection. One excellent resource, providing comprehensive coverage of options for local officials, is the Michigan Department of Natural Resources' recent publication, "Community Planning & Zoning for Groundwater Protection in Michigan: A Guidebook for Local Officials." Chapter 8 contains a complete list of available resources.

C. FOR BUSINESS AND INDUSTRY

Business and industry, especially those that handle hazardous materials, need to know of regulations protecting groundwater. In many states, the department of commerce (or equivalent) and hazardous waste management agency are the best information sources. One innovative educational strategy for reaching businesses is with a groundwater compliance inspection or "environmental audit" related to hazardous materials. Implemented by county and local health departments, these help to inform businesses about practical methods for protecting groundwater and avoiding legal liability. Such an audit can also be conducted by internal staff, outside consultants, or any combination of the above.

D. FOR THE AGRICULTURAL COMMUNITY

Outreach and education for the agricultural community, which includes family farmers, pesticide and fertilizer applicators, farm managers, and nurseries, is a very important component of any groundwater protection program. The primary need is for information to help the agricultural community more efficiently handle, use and dispose of fertilizers, pesticides, and livestock wastes.

One valuable source of information about programs for the agricultural community is the local or county Cooperative Extension. County Extension Agents are affiliated with the land grant universities. Another important information source is the Soil Conservation Service's field or area offices listed in the telephone directory under "Federal Government, U.S. Department of Agriculture." For a discussion of the Soil Conservation Service, its role in groundwater protection and technical assistance, see Chapter 7. Other important contacts are your Land Conservation Planning Department, Soil and Water Conservation District office, and your local public health department.

An excellent example of educational material developed for the agricultural community is the Farmstead Assessment System (Farm*A*Syst) which was developed as a cooperative project of the University of Wisconsin Extension, Cooperative Extension; Minnesota Extension Service; and the U.S. Environmental Protection Agency-Region V. Farm*A*Syst is a series of worksheets designed to assist farmers in evaluating the potential effect of their farmstead practices and structures on drinking water supplies. In addition, the work sheets provide contacts and references as well as an overall evaluation form which helps farmers decide which (if any) improvements are needed most and how to most efficiently use their time and money.

E. FOR THE GENERAL PUBLIC

5. What role does public education play in groundwater protection?

Education of the general public provides an essential link in efforts to protect groundwater. Public education should emphasize a hands-on approach, seeking to give citizens the tools and knowledge needed to understand their role and responsibility for groundwater protection.

The general public must play an important role in voluntary efforts, such as changing household practices, which may contaminate groundwater. The general public can also provide community support that local governments need for implementing regulatory programs.

6. What are the most effective ways to increase public awareness of groundwater issues?

Given the pervasive influence of Great Lakes surface and groundwater on the economy, environment and quality of life of the citizens of the United States and Canada, one might assume that related educational materials would have an equally pervasive presence in the K-12 classroom curriculum and informal education settings. In reality, however, this is not the case. A 1988-89 study by the Great Lakes Commission found that both classroom and informal education on Great Lakes issues is limited in scope, largely undocumented and varying greatly in focus and depth. A concern has also been expressed that a well-defined Great Lakes education network does not exist, a situation that inhibits information exchange and compromises the potential for the development and use of surface and groundwater education materials.

There are many avenues through which institutions in the Great Lakes region may approach education for the general public, but perhaps most important is how groundwater issues are presented. If the hope is to motivate people to take preventive action before groundwater contamination becomes a direct threat to them, then many would argue that educational efforts must focus on public stewardship. In order to promote such internal motivation for groundwater protection efforts, educational emphasis should be placed on groundwater's importance in terms of economics, drinking water supplies, public health, and the environment. These are the types of approaches which promote action not only for self-interest but also for reasons of citizenship, democratic responsibility, community pride.

All of the Great Lakes states and Ontario have developed groundwater education materials for the general public. These diverse groundwater education resources include: fact sheets, citizen's guides, audiovisual aids, speakers bureaus and many more that address specific groundwater issues. Too often, however, these materials never reach the general public until a serious groundwater contamination problem has occurred. Only Illinois, as mandated by state law, has full-time staff working on groundwater education.

There are also outstanding public groundwater education programs in the region that are non-governmental. Some of these, like the W.K. Kellogg-funded Groundwater Education in Michigan (GEM) program provide much needed public outreach that economically strapped governments are just not able to provide.

Chapter 6

COMMUNITY AND CITIZEN INVOLVEMENT: WHAT YOU CAN DO

Building upon the groundwater basics covered so far, this chapter addresses the critically important role of citizen and community involvement in protecting our groundwater resources.

Protecting groundwater requires awareness, knowledge, and participation from everyone. This chapter responds to these requirements by providing answers to critical questions about how individuals and communities can become informed and actively participate in protecting groundwater resources. You can assist community officials by asking some very specific questions and becoming an expert on your community's groundwater. The critical questions that follow are examples of the kinds of questions that individuals may wish to ask.

A. BECOME INFORMED

1. What information do you and your community need to protect groundwater and water supplies?

Since each community has unique groundwater resources, conditions, issues or problems, groundwater protection efforts should be adapted to the specific needs of your community. In order to effectively develop and/or participate in your community's groundwater protection programs, you will need a basic understanding of groundwater resources and protection needs in your area.

In addition, you will need a basic understanding of your community's: water supply system; hydrogeologic/groundwater setting; actual and potential contamination sources; laws and regulations affecting groundwater and the government agencies responsible for their implementation; and land use policies.

2. Where does your community's water supply come from?

Learning where your drinking water comes from and the path it travels to get to your home is an important first step in the information gathering process. Does your water come from a well on your property, a community well, or from surface water such as a local river or one of the Great Lakes? Contact your county health departments or state natural resources or environmental protection agencies listed in the Chapter 7 to answer this question.

Knowing this, you will be able to identify areas for further investigation and even suggest groundwater protection practices presented in this guidebook such as wellhead protection and septic tank maintenance. Remember, because of the interaction between groundwater and surface water, groundwater protection is critical to maintaining the quality of all of these water sources.

3. Where can I obtain groundwater and geologic information for the vicinity of my home or school?

Valuable information pertaining to local hydrogeologic conditions, including soil types, location, depth, and characteristics of your aquifer system should be the information sources listed in Table 6-1, your local library or even the geology or engineering department of a local university or college.

You will also need a local topographic map, groundwater and geologic maps (if available), and a good textbook on the region's hydrogeology. A sampling of critical questions you should ask include:

- What area and jurisdictions does the aquifer cover?
- How vulnerable to contamination is the, aquifer and where are the critical recharge areas?
- Who depends on groundwater and who manages groundwater withdrawals in the community?

Table 6-1
Selected Sources Of Groundwater Information

A. Geologic Conditions
- State geologic surveys
- State bureaus of mines
- State natural resource agencies
- U.S. Geological Survey

B. Soils, Drainage, and Agricultural uses
- U.S. Department of Agriculture
- State land-grant colleges
- County extension agents

C. Topography
- U.S. Geological Survey

D. Groundwater Resources and Water Testing
- State natural resources or environmental protection departments
- State water resources departments
- Local health departments
- U.S. Geological Survey
- National Ground Water Association

E. Water Supply and Septic-System Construction
- State and local health departments
- State environmental or conservation departments
- County extension agents
- U.S. Environmental Protection Agency

F. Land Use and Zoning
- State planning agencies
- County and local zoning and planning agencies

Adapted from *Ground Water and the Rural Homeowner*, a pamphlet by the USGS, 1988.

- Are well logs, records of the soil and rock encountered in the drilling process, available for my area?

4. What is the current quality of your community's groundwater supplies?

You will want to know what the bacterial and chemical components of your drinking water are and what testing or monitoring of groundwater quality currently exists. Private well owners are solely responsible for testing their well water supply. Your county health department or local water supply agency may offer inexpensive testing for bacteria and commonly occurring constituents such as iron and chloride.

These agencies are also the best sources of information about the quality of water withdrawn from public wells Testing for human- induced chemical contamination is potentially very expensive and must be narrowed down to a limited set of tests based on knowledge of the potential contaminant source.

5. What actual or potential sources of groundwater contamination are present in your community?

You need to determine the existing and potential threats to groundwater in your community. Review Chapter 3 on local land use activities and groundwater quality. Identify land use activities in your community which have the potential to contaminate groundwater. Consider critical questions including:

- Are there activities that involve manufacturing, processing, or handling of toxic materials?
- Are activities which have the potential to contaminate groundwater carefully regulated?
- Are these activities occurring in close proximity to community wells, vulnerable aquifers, or aquifer recharge areas?
- How are the hazardous wastes generated in your community stored and disposed of?

State and county agencies may be able to help you identify actual or potential sources of groundwater contamination. Under the community right-to-know provisions of the 1986 Comprehensive Environmental Response, Compensation and Liability Act (Superfund), states are required to establish emergency planning committees. These committees receive reports from companies detailing the use of certain hazardous substances; serious environmental releases are reported immediately. Another source of information is the U.S. EPA's Toxic Chemical Release Inventory (TRI), a publicly accessible data base recording environmental releases and extensive information on plants manufacturing, processing, or use of the reported chemicals.

Your fire department may be a good local source of information on both toxic and/or hazardous material use as well as the location of underground storage tanks in your community.

6. What is your state or local government doing to protect groundwater?

It is important to learn what your state or local government is doing to protect groundwater. General information and important contacts for your state or province's groundwater protection efforts appear in Chapter 7. You will want to contact these agencies to get a copy of your state or province's groundwater protection strategy and to begin asking critical questions such as:

- What are the responsibilities of the various state and local agencies involved in groundwater protection and how are they coordinated?
- Is the state assisting local governments to: adopt municipal ordinances and land use controls to prevent groundwater contamination; develop wellhead protection programs, and protect critical recharge areas?

B. PARTICIPATE IN GROUNDWATER PROTECTION PROGRAMS

7. Why must citizens take an active role in protecting groundwater?

The importance of groundwater in the Great Lakes region, its vulnerability and need for protection has been emphasized throughout this guidebook. We have also focused on the need for strong and consistent government leadership in developing groundwater protection programs. As recognized repeatedly in state policy documents, however, the political will and motivation needed to establish and effectively implement such programs is dependent upon an active and well-informed citizenry. Educated citizens not only lend their critical voice in government policy/decision-making, but can also take personal steps in educating themselves and their community on simple steps to prevent groundwater contamination at home.

8. What role can citizens play in assisting local governments to protect groundwater?

Whether or not your community has started or has already developed its own groundwater protection program, your active participation can make the difference between success and failure. Along with becoming knowledgeable about your community's groundwater, **get involved in groundwater management.** Local governments have considerable authority to plan and regulate for groundwater protection. Citizen participation in the local planning and implementation process can strengthen local government efforts.

Stay informed about local land use and waste disposal issues. As you learned in Chapter 3, urban and rural land uses, if not carefully planned and constructed, can adversely impact groundwater quality. City, township, and county governments have considerable power to make land use zoning decisions which protect groundwater. Some communities facilitate public participation through groundwater policy advisory committees, environmental review boards, or planning commission meetings. Your elected or appointed officials may not know the importance of groundwater to your community or the groundwater protection options available to local governments. Find out about public hearings and meetings where you can learn more, express your views, and become part of the decision making process which affects local and statewide groundwater issues.

Become a groundwater watchdog. Report illegal or abandoned waste sites or incidents of improper waste disposal in your community. Stay alert. Don't hesitate to call a state or local official if you see someone dumping waste illegally or discover an abandoned dump site with old barrels. Most jurisdictions are understaffed and rely on you to report evidence of groundwater contamination.

9. How can I mobilize public participation to protect groundwater?

While there is much you can accomplish by yourself, your efforts will be multiplied by building community support for groundwater protection. Mobilizing public participation requires that you spread the word by contacting other groups and individuals in the community. You can find support among the local agencies and organizations listed in Table 6-2, many of whom will have interests similar to yours. Coalitions of such community organizations will lend weight to

Table 6-2

Local Agencies and Organizations: Partners in Community Groundwater Protection

- City or county health departments
- Water supply companies
- Community civic and service organizations such as the League of Women Voters, Parent Teacher Association, Rotary Club, and Jaycees
- Local medical society
- Neighborhood associations
- Business organizations and associations, such as the Chamber of Commerce
- Cooperative Extension
- Daily and weekly newspapers
- Local environmental groups
- Citizen's organizations

Adapted from *Groundwater Contamination: Working in Partnership with Communities*, Institute for Comparative and Environmental Toxicology, Cornell University, 1990.

Americans' Do-It-Yourself Ethic Revisited

International shock accompanied the *Exxon Valdez* spill of **11.7 million** gallons of oil into Alaska's Prince William Sound. Who notices the widespread contamination caused by Americans changing their own oil? Each year these economy-minded Do-It-Yourselfers pour **400 million** gallons — 35 times the amount of the *Exxon Valdez* spill — on the ground and into landfills. Much of this oil will eventually reach the groundwater table. The average oil change of four quarts of used oil is enough to contaminate more than one million gallons of fresh water. Heightened public awareness and high profile recycling programs are clearly an imperative of the 1990s.

your efforts and provide resources such as technical expertise, office support, and opportunities for outreach to a broad audience in the community.

C. GROUNDWATER PROTECTION AT HOME

Groundwater protection begins in your own home! While educating yourself and participating in local government groundwater protection efforts are essential, each of us must also examine our habits around the home. Everyday activities from bathing to home maintenance chores can affect groundwater quality.

10. What are household hazardous wastes and green consumerism?

Hazardous wastes that contaminate groundwater are not created by industry alone. The average U.S. household generates about 15 pounds of hazardous waste each year. When added up, these household hazardous materials generate a tremendous quantity of hazardous waste that, if not properly used and disposed of, can lead to contamination of groundwater and drinking water supplies.

Household hazardous wastes are commonplace in all parts of the home. Some typical examples include: batteries; cleaners; polishes; automotive fuels and additives; paints, solvents; and gardening chemicals. The first step to safe responsible management of household hazardous waste is proper use of the product according to the directions on the label. Depending on the product's toxic or hazardous components, proper disposal may include: drain disposal; sanitary landfilling; or special hazardous waste disposal.

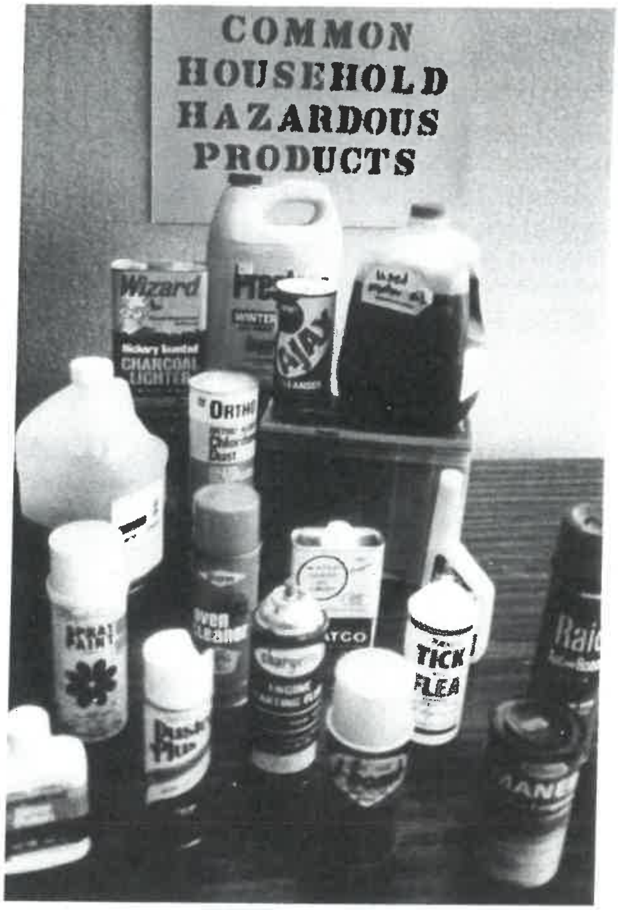
The best way to respond to the household hazardous waste dilemma is to become a green consumer. Becoming a green consumer means making environmentally conscious consumer choices; buying products that minimize environmental degradation and help to protect groundwater. Your choice of products should take into account the ecological impacts associated with the entire life cycle of the product by recognizing the environmental impacts associated with both the product's end-of-line or disposal impacts, and also those impacts associated with its use and production process.

Cleaning Up Your Own Act – Examples of Homeowner Actions to Protect Groundwater

Groundwater protection must take place on the community, state, and national levels. However, individuals also play a critical role in protecting groundwater. Here are six ways you can do your part by protecting groundwater in your own back yard!

- Use and dispose of household hazardous materials appropriately.
- Maintain home septic systems properly.
- Have home wells tested regularly.
- Become a green consumer.
- Conserve water.
- Support local government efforts to protect groundwater.

Green consumers look for non-toxic alternatives to household hazardous waste and follow the three R's of environmental consciousness: reduce, reuse, and recycle. The most important of these, reduce or

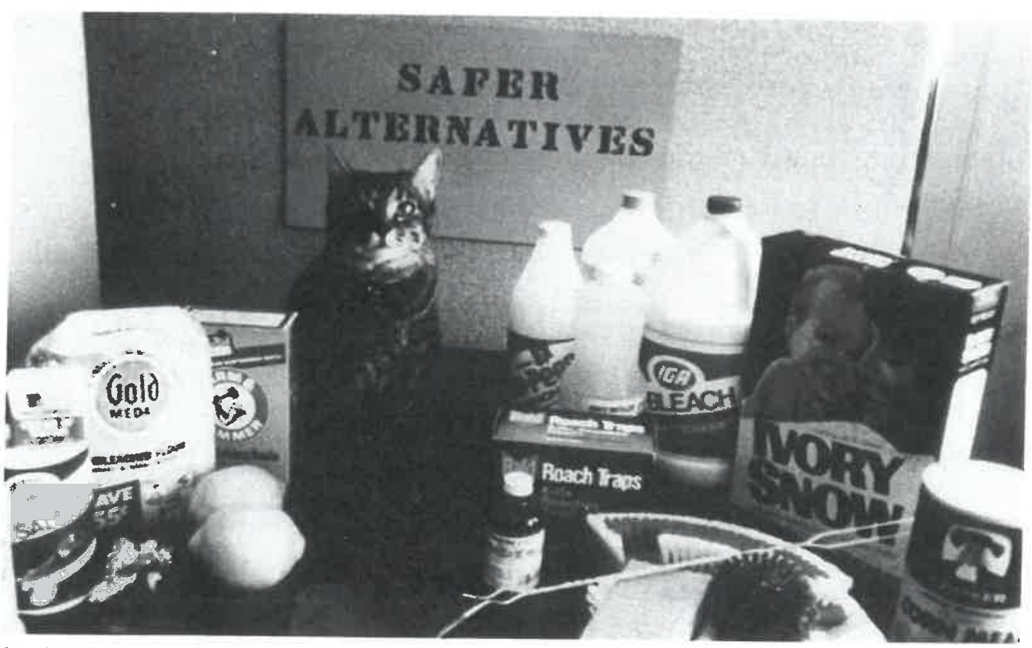


Common household hazardous products.
Source: Illinois Department of Energy and Natural Resources

Illinois' Household Hazardous Waste Collection Program Growing

The Illinois Environmental Protection Agency successfully completed eight Household Hazardous Waste Collection projects during 1991 and is planning to conduct 15 collection projects in 1992. 2,927 residents participated in the pickups which collected a total of 874 drums of household hazardous wastes and 114 cubic yards of latex paint. Information about collection programs in your jurisdiction can be obtained by contacting the state agency contacts listed in Chapter 7.

source reduction, means cutting off the problem at its source of production by stopping the consumer demand for products which over-burden the environment with unnecessary packaging, energy consumption, or hazardous contents. Find out more about becoming a green consumer. You will save money and help protect groundwater and other precious natural resources. For those household hazardous materials for which you cannot find a safe, effective alternative, inquire about the proper location for hazardous waste disposal. If you change your own automotive oil, identify and use your community's collection center for used motor oil. Many communities sponsor periodic household hazardous waste collection days that promote awareness and save the community the long-term costs and liabilities associated with improper hazardous waste disposal. Your state or county environmental agencies should be helpful information sources on household hazardous waste and green consumerism.



Safe alternatives to hazardous products. Source: Illinois Department of Energy and Natural Resources

Chapter 7

WHERE TO OBTAIN HELP: GROUNDWATER INFORMATION, ASSISTANCE, AND PROTECTION PROGRAMS

This chapter outlines federal, state and provincial groundwater protection programs in the Great Lakes region. Due to the increasing importance and awareness of groundwater protection issues, governments have responded with an increasingly large and complex network of agencies, programs, and legal initiatives addressing groundwater protection. Although this trend is encouraging, the current government structure may be overwhelming to those unfamiliar with groundwater management issues.

This chapter serves as a reference guide for deciphering the roles and responsibilities of the myriad of groundwater-related programs. It provides readers an easily accessible guide to the most pertinent groundwater protection programs in their jurisdiction. In addition, Section D provides information and contacts for academic and non-governmental institutions and programs relevant to groundwater protection.

Federal program information for both the United States and Canada is summarized by agency in alphabetical order; the United States first, then Canada.

Information for each state and provincial jurisdiction is organized under the following categories:

1) Key Groundwater protection issues (groundwater resources, usage, contamination)

2) Groundwater protection programs (legislation, program elements, financial and technical assistance, public education)

3) Key agency contacts (addresses and phone numbers)

Information for this chapter was provided by state, provincial and federal task force members or contacts; descriptions will vary in level of detail. If agency addresses and phone numbers have changed, call the Great Lakes Commission at (313) 665-9135 for updated information.

A. FEDERAL PROGRAMS — UNITED STATES

A national groundwater protection program was first established in 1984 when the U.S. Environmental Protection Agency (EPA) published a national Ground Water Protection Strategy. At present, however, there is no federal legislation specifically addressing the problem of groundwater contamination. Instead, there are eight federal environmental laws, directed primarily at other environmental issues, which serve to regulate groundwater. These laws include:

- Safe Drinking Water Act (SDWA);
- Federal Water Pollution Control Act ("Clean Water Act");
- Resource Conservation and Recovery Act (RCRA);
- Toxic Substances Control Act (TSCA);
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund);
- Federal Insecticide, Fungicide and Rodenticide Act (FIFRA);

These laws give regulatory authority to various federal agencies, the most prominent of which are the EPA and the Department of Interior (see Table 7-1).

United States Environmental Protection Agency (U.S. EPA)

Ground Water Protection Division
WH-550G
401 M Street
Washington, D.C. 20460
(202) 260-7077

The U.S. EPA is the primary federal agency responsible for the nation's groundwater protection program. Prior to 1984, when the EPA published the national Ground Water

Table 7-1
Federal Groundwater-related Laws

Safe Drinking Water Act (1974, amended 1986)
The Act provides the EPA greater control over groundwater since the 1986 amendments.
- Sets maximum contaminant levels (MCLs) for drinking water
- Promotes groundwater protection through the special designation of "sole-source aquifers" that are the principle source of an area's drinking water
- Regulates deep-well injection of wastes to protect groundwater
- Requires states to develop Wellhead Protection (WHP) programs to protect municipal groundwater supply wells

The Clean Water Act (1972, amended 1987)
- Gave EPA authority over contamination of "the nation's water"
- The 1987 amendments increased emphasis on groundwater quality and include: requirements for states to develop nonpoint source pollution prevention strategies and also provides grant moneys for groundwater protection efforts

The Resource Conservation and Recovery Act (1976)
- Regulates the handling, transport, and disposal of solid and hazardous wastes
- Mandates groundwater monitoring at landfills
- Sets standards to minimize the contamination threat from leaking underground storage tanks

The Toxic Substances Control Act (1976)
- Empowers the EPA to regulate all phases of the toxic chemical industry, from production to disposal
- Empowers the EPA to test and potentially ban any chemicals posing an unreasonable risk

Comprehensive Environmental Response, Compensation, and Liability Act (Superfund) (1980)
- Provides money for cleanup of abandoned hazardous waste sites
- Prioritizes the most serious sites on a National Priority List

Federal Insecticide, Fungicide, and Rodenticide Act (1947, amended 1972, 1978)
- Affects the agricultural sector in particular because it regulate the marketing and use of pesticides
- Classifies pesticides for general or restricted use; state departments of agriculture "certify" users of restricted-use pesticides

Protection Strategy, a patchwork of federal and state authorities provided a fragmented and ineffectual system for groundwater protection. To address these shortcomings, the 1984 strategy focused the EPA's efforts on four major objectives:

- Strengthening state groundwater programs;
- Addressing major sources of contamination;
- Establishing groundwater policy direction and program consistency; and
- Coordinating EPA programs.

The latest policy, articulated in "Protecting the Nation's Groundwater: EPA's Strategy for the 1990s" addresses gaps in protection efforts across the country by promoting *comprehensive* protection at the state and local level. This new strategy is intended as an aggressive and comprehensive approach to groundwater protection that will clarify EPA policy and its relation to state programs; emphasize groundwater *protection;* and coordinate funding to give incentives to states showing progress in their individual programs.

The EPA recognizes that "groundwater management and protection is inherently a state and local responsibility." One of the key elements of EPA's new strategy is the development of "Comprehensive State Groundwater Protection Programs." These programs are intended to build on current state activities and to fill in the gaps in the state's groundwater protection efforts.

In addition to assisting state programs, the EPA is working on other groundwater protection fronts including: controlling hazardous products such as pesticides and toxic chemicals; controlling contaminant sources, such as waste disposal and chemical storage facilities; cleaning up contaminated sites; researching national groundwater issues; and providing resources for groundwater education.

For further information contact the appropriate regional office:

U.S. EPA Region 5
Ground Water Protection Branch
5WG - 16J
U.S. EPA, Region V
77 West Jackson Blvd.
Chicago, IL 60604
(312) 886-1490

Region 5 includes:
Six Great Lakes Basin States:
Illinois
Indiana
Michigan
Minnesota
Ohio
Wisconsin

U.S. EPA Region 2
Office of Ground Water
Water Management Division
U.S. EPA, Region II
26 Federal Plaza
New York, NY 10278
(212) 264-5635

Region 2 includes:
New York
and outside the Basin:
New Jersey
Puerto Rico

U.S EPA Region 3
Office of Ground Water
Water Management Division
U.S. EPA, Region III
841 Chestnut Street
Philadelphia, PA 19107
(215) 597-2786

Region 3 includes:
Pennsylvania
and outside the Basin:
Maryland
Virginia
W. Virginia

U.S. Department of Commerce
National Oceanic and Atmospheric Administration (NOAA)
Great Lakes Environmental Research Laboratory (GLERL)
2205 Commonwealth Blvd.
Ann Arbor, MI 48105-1593
(313) 668-2235

GLERL does research on high lake levels, toxic contamination, and other pressing environmental problems in the Great Lakes Basin. Their research has important implications for understanding the role of groundwater in the hydrologic cycle of the Great Lakes Basin. Using computer models to predict the overall role of evaporation, surface runoff, snowmelt, etc., within the Basin's water budget, GLERL helps estimate the groundwater contribution to Great Lakes surface water.

U.S. Department of Agriculture (USDA)
Office of the Secretary
Washington, D.C. 20250
(202) 447-3631

The President's Water Quality Initiative, begun in 1989, calls for voluntary cooperation in improving water quality. As part of this initiative, the Soil Conservation Service (SCS), the Cooperative Extension Service (CES) and the Agricultural Stabilization and Conservation Service (ASCS) are cooperating to provide technical assistance, educational efforts and financial assistance to rural landowners to address water quality issues. They share leadership for hydrologic unit area, demonstration, and water quality special projects. Many of these projects address groundwater issues. Specific information on assistance programs is provided by the Michigan office of the SCS, the designated office for coordination of Great Lakes activities.

USDA-Soil Conservation Service (SCS)
1405 S. Harrison Road, Room 101
East Lansing, MI 48823
(517) 337-6702

All SCS offices provide technical assistance on soil and water conservation issues, and can offer the following:

- Information on soil types and geographic areas for use in assessing the vulnerability of groundwater to contamination;
- Educational and technical assistance to farmers and rural landowners to help them develop conservation systems and practices, such as pesticide and fertilizer management, that can minimize the risks of groundwater contamination;
- Coordination with state, local and other federal agencies to facilitate technology transfer to agricultural land users;

- Assistance to state water quality management agencies, to develop and implement or diffuse nonpoint source pollution-management programs as required by Section 319 of the Water Quality Act of 1987.

For further information contact the appropriate SCS state office:

Illinois	(217) 398-5267
Indiana	(317) 290-3675
Michigan	(517) 337-6718
Minnesota	(612) 290-3675
New York	(315) 423-5521
Ohio	(614) 469-6962
Pennsylvania	(717) 792-2202
Wisconsin	(608) 264-5577

For local information, contact field or area offices listed in the telephone directory under "Federal Government, U.S. Department of Agriculture."

United States Department of the Interior

National Park Service (NPS)
Water Resources Division
301 South Howes St., Room 335
Ft. Collins, CO 80521
(303) 221-8305
or
Midwest Region
Omaha, NE
(402) 221-3438

The National Park Service's policy on "Protection of Surface and Ground Waters" seeks to manage and protect lakes, streams, rivers and groundwater as integral components of park aquatic and terrestrial ecosystems. This policy is implemented consistently with the Clean Water Act (33 USC 1251 et seq.) and other applicable federal, state, and local laws and regulations. Park waters, either surface or groundwaters, will be withdrawn for consumptive use only where such withdrawal is absolutely necessary for use and management of the park and where it will not significantly alter natural processes and ecosystems.

Consistent with this policy of groundwater protection and management, the NPS monitors groundwater quantity in and near some parks. This monitoring is performed primarily in the context of activities adjacent to parks, such as abandoned landfill or tailing ponds, that may potentially impact a park's groundwater. While not a central focus of the park's programming, research and education concerning groundwater are often part of a park's interpretive programs regarding park resources and values. An example is the environmental education program at Indiana Dunes National Lakeshore, where groundwater is central to the maintenance and functioning of the dunes and wetlands ecology that characterize the area.

U.S. Geological Survey (USGS)

Water Resources Division - Northeast Region
12201 Sunrise Valley Drive, MS 433
Reston, VA 22092

USGS activities in the Great Lakes region are coordinated by three regional offices and projects are implemented by local district offices in each state. All USGS offices provide technical assistance on groundwater, surface water, and water quality issues. The USGS works on a variety of groundwater investigations involving flow modeling, water quality analysis, water resources management, and groundwater to surface water interaction. The USGS often works with other federal and state agencies to provide expertise in these types of investigations. District offices are involved in disseminating local information to educational institutions by presenting lectures, showing slides and videotapes, and answering requests for information.

For further information on regional coordination of Great Lakes groundwater activities or local activities, contact the appropriate office:

Illinois District	(217) 398-5353
Indiana District	(317) 290-3333
Michigan District	(517) 377-1608
Minnesota District	(612) 229-2600
*New York District	(516) 938-8830
*Ohio District	(614) 469-5553
Pennsylvania District	(717) 782-4514
Wisconsin District	(608) 274-3535

*Designates that this office is an Assistant Regional Office.

U.S. Army Corps of Engineers (COE)

North Central Division
16th Floor
11 North Canal Street
Chicago, IL 60606-7025
(312) 353-6319

The COE has a mission to plan, design, construct, maintain and operate civil works water resources projects; to provide engineering support for other agencies involved in hazardous and toxic waste remedies; and to regulate certain activities in the waters of the United States. For any such projects which involve potential impacts on groundwater, specialized experience is used to develop data pertaining to local surface and groundwater hydrology and geology. The COE, therefore, is a source of information and expertise on matters dealing with groundwater, including: elevation, permeability, water quality, soil types, and areas of recharge. Data is more detailed for areas within the vicinity of COE federal projects.

Information on COE involvement with groundwater can be obtained by contacting the appropriate district office:

Buffalo District
New York, Ohio, Pennsylvania
(716) 879-4209

Chicago District
Illinois
(312) 353-6412

Detroit District
Indiana, Michigan, Minnesota, Wisconsin
(313) 226-4680

B. FEDERAL PROGRAMS — CANADA

As in the U.S., the Canadian Federal Government's role in groundwater protection is largely supportive of the local or provincial role. In this capacity, several federal agencies conduct research on groundwater issues and conduct field investigations of groundwater contamination associated with federal facilities. Through the Great Lakes Action Plan the federal government has committed $125 million dollars, over 5 years, to assist in restoring the water quality of the Great Lakes Basin and to address the new requirements of the amended Great Lakes Water Quality Agreement (GLWQA). A significant portion of these funds are being directed at groundwater issues being addressed by Environment Canada and Agriculture Canada.

The Canada/Ontario Agreement Respecting Great Lakes Water Quality (COA) has helped to coordinate federal and provincial efforts to protect groundwater. Under this Agreement a groundwater committee is charged to:

1) Ensure the identification of existing and potential sources of contaminated groundwater affecting the Great Lakes;
2) Coordinate the mapping of hydrogeological conditions in the vicinity of existing and potential sources of contaminated groundwater;
3) Facilitate the development of standard approaches and internationally agreed procedures for sampling and analyzing contaminated groundwater; and
4) Oversee the management of groundwater contamination sources and contamination sites.

Environment Canada

Inland Waters Directorate
P.O. Box 5050
867 Lakeshore Drive
Burlington, Ontario L7R 4A6
(416) 336-4908

Environment Canada plays a leadership role in groundwater management, supporting provincial groundwater protection efforts and education programs. Groundwater, as an integral part of the hydrologic cycle, is included in many of Environment Canada's publications, which are useful for educational purposes. To obtain copies write or call:

Editorial and Publications Section
Inland Waters Directorate
Environment Canada
Ottawa, Canada K1A OH3
(819) 997-2601

Environment Canada - National Water Research Institute (NWRI)
Inland Waters Directorate
P.O. Box 5050
867 Lakeshore Drive
Burlington, Ontario L7R 4A6
(416) 336-4625

The Groundwater Contamination Project of the NWRI includes a diversity of technical research in the field of contaminant hydrogeology. This includes: investigation of the movement, fate, and remediation of contaminants; development of new groundwater monitoring techniques; and the development of standard analytical methods for characterizing hazardous waste in groundwater.

Agriculture Canada
Land Resource Research Center
Sir John Carling Bldg.
930 Carling Avenue
Ottawa, Ontario K1A OC5
(613) 995-5011

Through the Great Lakes Action Plan, Agriculture Canada's Land Resource Research Center has developed a major program investigating the contamination of groundwater from agricultural chemicals.

C. STATE AND PROVINCIAL PROGRAMS

ILLINOIS

1. Key Groundwater Protection Issues

Groundwater Resources. Northern Illinois has large groundwater resources. Deep, thick sandstone aquifers commonly provide a major water supply with high yields. Many unconsolidated, surface aquifers of sand and gravel also provide important sources of public water supply. Groundwater also contributes a large portion of surface water flow in Illinois through discharge to streams and rivers. Although groundwater contamination is a major concern in highly urbanized, northeastern Illinois, another major issue is aquifer mining, as pumpage from the deep sandstone aquifers in the region exceeds recharge.

Groundwater Usage. About 5.5 million people, or nearly 50 percent of Illinois' population, rely on groundwater for their drinking water. For about 97 percent of the rural population in Illinois, groundwater is the only source of drinking water. Although Lake Michigan provides water to a large part of the Chicago metropolitan area, there are a many community water supply wells in this area. It is also the most industrialized area in the State and, thus, has the highest density of potential sources of groundwater contamination, such as chemical waste generators, landfills, and underground storage tanks. Although implementation of the 1987 Illinois Groundwater Protection Act's (IGPA) groundwater protection provisions has made a strong start, there is still a great need for coordinated action at the local level and more widespread public understanding of groundwater issues.

Groundwater Contamination.

- Of 19,136 private water well tests performed by the Illinois Department of Public Health in 1990, 33 percent showed coliform contamination and 8 percent exceeded the standard of 10 mg/l, $N\text{-}NO_3$.
- As of July 1992, 63,680 underground storage tanks at 24,639 facilities were registered with the State Fire Marshal. An estimated 20,000 additional tanks are not registered.
- As of August 1992, 8,267 incidents of leaking underground storage tanks were reported and 1,097 cleanups were completed, according to the Illinois Environmental Protection Agency.
- As of 1987, 121 hazardous substance cleanup sites were being managed by the EPA.
- About $920 million in public funds ($380 million state, $540 million federal) could be required between 1987 and the year 2000 to cleanup 100 sites and conduct some 234 immediate removals. For 1988, approximately $26 million in state funds were necessary for cleanup work.

- Two out of three acres of rural Illinois are treated with pesticides; annually, farmers apply approximately 50 million pounds of pesticides and 1 million tons of nitrogen fertilizer. Pesticides have been detected in some of the state's shallow aquifers (within 50 feet of the surface); these are particularly vulnerable and occur in 40 percent of rural Illinois.
- Animal waste from concentrated livestock operations have a significant potential for contaminating groundwater. Although their impacts have not been determined, it is estimated that there are over 50,000 feedlots in Illinois. These could pose threats to rural water wells, both community and private.
- Of 2,600 community water wells analyzed by Illinois Environmental Protection Agency, 115 (4.6 percent) have shown detections of volatile organic and aromatic constituents. Forty-one (1.6 percent) of these wells exceeded U.S. EPA final or proposed maximum contaminant levels.
- Sixteen community wells (2.2 percent of those tested) had detectable levels of pesticides. One of these wells exceeded standards for atrazine and alachlor and is being addressed by a $192,000 state grant to find an alternative water source. Although most of the affected wells are relatively shallow (37 to 117 feet) and in geologically susceptible areas, detections were also found in wells of 1,069 and 2,448 feet. Up to 11 of the 16 wells have agricultural chemical mixing and loading operations within 1,000 feet.
- Groundwater contamination advisories were issued for five community water supplies by the Illinois Environmental Protection Agency. Such hazard advisories are published when potential sources or routes of contamination "represent a significant hazard to the public health or environment." Potential sources include petroleum bulk terminals, landfills, commercial activities, and agricultural chemical dealerships.
- A pilot study of agricultural chemicals in randomly selected rural, private wells in selected study areas found agricultural chemicals in 55 of 240 samples drawn from 48 wells. Dug or bored wells and shallow wells were shown to be more vulnerable to contamination. Nitrate levels exceeded the standard in 42 of the samples. Thirty-two occurrences of nine different pesticides were detected in samples from 24 wells.
- Between 1987 and 1992, over 8,000 releases from underground storage tanks were reported. Cleanup objectives were met in this same period on about 700 of these sites.

2. Groundwater Protection Programs

Legislation and Policies. The 1987 Illinois Groundwater Protection Act (IGPA) is the primary legislation for groundwater quality in the state. Emphasizing a preventive approach, the IGPA provides innovative tools which both state agencies and local officials can use to limit activities that threaten to contaminate groundwater resources.

Program Elements. The major tools to be applied on a statewide basis include:

- A state policy "to restore, protect, and enhance the groundwaters of the state, as a natural and public resource."
- "Setback zones" to prohibit the siting of potential contamination sources too close to water wells.
- A "regional planning program," designed to control threats to groundwater resources which extend across local jurisdictions, including such approaches as "regulated recharge area."
- Illinois Pollution Control Board (Board) regulations to broadly restrict, monitor, and better control contamination-caus-

ing activities near water wells, within recharge areas and near other critical pathways to groundwater supplies.

- Investigation of the occurrence of agricultural chemicals in Illinois groundwater.
- "Minimal hazard certification program" to ensure that Board regulations can be applied flexibly, but without compromising protection goals.
- Statewide community well site surveys.
- A statewide program of groundwater resource assessments to enhance the state's groundwater database and to map the location of aquifers and recharge areas.
- A program of research in groundwater hydrology, the movement of contaminants through geologic materials, and technologies for groundwater restoration.
- Statewide groundwater monitoring network.
- A cooperative groundwater education program covering groundwater principles, issues, policy, contamination problems, testing, and protection measures.

Financial and Technical Assistance. Local governments are provided planning and regulatory tools to supplement these broad statewide programs with their own more stringent regulatory actions. They can:

- Expand setback zones to protect especially vulnerable groundwater supplies.
- Conduct groundwater protection needs assessments to provide early and comprehensive prevention of future contamination.
- Request that the EPA and Board establish a "regulated recharge area" if an expanded setback zone is not sufficient to protect a particular source of drinking water.
- Prevent pollution and punish polluters of any water supply source within twenty miles of their jurisdictional boundaries.

Public Education. While many of these groundwater contamination prevention tools are being used by other states, IGPA's mandated "groundwater protection education program" is unique. Implemented by a full time Groundwater Education Coordinator in the Department of Energy and Natural Resources (DENR), and in coordination with a strong public participation element of the state's environmental policy, the program targets all of Illinois' public and private sectors. Among the products of this exemplary program of public outreach and groundwater education are:

- Distribution of more than 80,000 copies of a pamphlet for the general public entitled, *The Illinois Groundwater Protection Act, A Safeguard for Illinois' Water Supply.*
- Development of groundwater protection workshops attended by the general public, state and local officials, and groundwater professionals.
- Observance each May of Groundwater Protection Month, including field days and demonstrations.
- Development of a groundwater education activity guide; 4,000 have been distributed to teachers, mostly through workshops.
- Groundwater Speaker's Bureau.
- Educational programs in priority regional areas.
- Referral system and clearinghouse with an 800 number.
- Loan program for videos, slide sets, groundwater models and groundwater displays, in association with the state library system.
- Groundwater protection awards program.

- Outreach program geared to presentations at professional level meetings as well as public events such as state and county fairs.
- Groundwater videos, public service announcements and video press releases shown by public and private TV stations.

In addition, the State Water Survey and State Geological Survey respond to hundreds of varied information requests annually.

3. Key Agency Contacts

Referral, educational materials, or groundwater speakers:

Illinois Department of Energy and Natural Resources
825 W. Adams Street
Springfield, IL 62704-1892
(217) 785-2800

Concerns about private, semi-private, community-public, monitoring and closed-loop heat-pump wells, contact your local health department or:

Illinois Dept. of Public Health
Division of Environmental Health
525 W. Jefferson Street
Springfield, IL 62761
(217) 782-5830

Concerns about mining, oil and gas, or injection wells related to oil and gas:

Department of Mines and Minerals
Oil and Gas Division
300 West Jefferson Street
Springfield, IL 62702
(217) 782-5830

Concerns about community wells:

Illinois Environmental Protection Agency
2200 Churchill Road, P.O. Box 19276
Springfield, IL 62794-9276
(217) 785-4787

Concerns about hazardous wastes and their disposal:

Hazardous Waste Research and Information Center
One East Hazelwood Drive
Champaign, IL 61820
(217) 333-8940

Concerns about agricultural chemicals:

Illinois Department of Agriculture
P.O. Box 19281
Springfield, IL 62794
(217) 785-2427

Concerns about groundwater quantity management and law:

Illinois Dept. of Transportation
Division of Water Resources
2300 S. Dirksen Parkway
Springfield, IL 62764
(217) 782-0690

Concerns about underground storage tanks:

Office of the State Fire Marshal
1035 Stevenson Drive
Springfield, IL 62703
(217) 785-1020

For information about the quantity or quality of groundwater or about geological resources:

Illinois State Water Survey
2204 Griffith Drive
Champaign, IL 61820
(217) 333-4300

Illinois State Geological Survey
615 E. Peabody
Champaign, IL 61820
(217) 333-4747

For local education programs contact your county Cooperative Extension Office or:

University of Illinois Cooperative Extension Service
122 Mumford Hall
1301 West Gregory
Champaign, IL 61801
(217) 333-2660

INDIANA

1. Key Groundwater Protection Issues

Groundwater Resources. Within the Great Lakes Basin, Indiana has moderate to excellent supplies of groundwater that can be commonly found in surface aquifers of sand and gravel. Although the water quality is generally good, the aquifers, being highly permeable and shallow, are vulnerable to pollution and must be carefully managed to ensure their protection.

Groundwater Usage. Nearly 60 percent of Indiana's five million residents rely on groundwater for their drinking water supply; within the Basin portion of the state a third of total public domestic and industrial water supply comes from groundwater withdrawals. Despite the economic and social significance of its groundwater supply, Indiana's water resource professionals face a critical lack of data on the state's groundwater resources.

Groundwater Contamination. Like all of the Great Lakes States, Indiana has a host of groundwater contamination issues, both documented and threatening. Some of Indiana's critical groundwater contamination issues include:

- Over the last few years at least 17 public water supply wells in Indiana were closed due to some type of contamination.
- Approximately one-fourth of public well fields are located in particularly vulnerable aquifers and are near potential sources of contamination.
- Hazardous material spills account for approximately 13 percent of the incidents of groundwater contamination in Indiana.
- Indiana is estimated to have more than 60,000 underground storage tanks; leaking underground storage tanks account for approximately 17 percent of known incidents of groundwater contamination in the state.
- Improper management of runoff at state, county, city and private salt storage facilities has led to numerous documented cases of groundwater contamination.
- Abandoned waste disposal sites have caused groundwater contamination in many locations; 29 of Indiana's hazardous sites are listed on the National Priorities List under Federal Superfund legislation.
- Over one-fourth of Indiana's known groundwater contamination sites have unknown or unconfirmed sources.

2. Groundwater Protection Programs

Legislation and Policies. In 1989, the Indiana Groundwater Protection Act (IGPA) institutionalized the state's Groundwater Task Force which coordinates activities among state agencies working on implementation of the State Groundwater Protection Strategy. The IGPA also mandated the development of a wellhead protection strategy, groundwater quality standards, regulations for wastewater impoundments, and provided for funding of the groundwater protection program.

Program Elements. Indiana's Saint Joseph aquifer (in the Great Lakes Basin) is the state's only federally designated Sole Source Aquifer. This designation prohibits new underground injection wells in the area without the establishment of an underground injection control (UIC) program and also prohibits new federal funding for any project in the area that might have the potential to contaminate the aquifer. This designation does not, however, prohibit the much larger number of potential projects which are not federally funded.

Many of the state's program needs, detailed in the State Groundwater Strategy in 1987, including enhanced interagency coordination, wellhead protection, and basic groundwater resource data management, are now being addressed. On the local level, the Michiana Area Council of Governments (MACOG) is involved in wellhead protection planning and serves as a model for other regional agencies. Elkhart County (also within the Great Lakes Basin) has developed a model Groundwater Protection Ordinance which deals primarily with the registration of hazardous materials.

3. Key Agency Contacts

Indiana Department of Natural Resources
Division of Water
402 W. Washington Street
Room 264W
Indianapolis, IN 46204
(317) 232-4160

Office of the State Fire Marshal
402 W. Washington Street, Room 241E
Indianapolis, IN 46204
(317) 232-2226

Indiana Department of Environmental Management (IDEM)
Ground Water Section
105 S. Meridian
P.O. Box 6015
Indianapolis, IN 46225
(317) 233-4237

IDEM 24 Hour Emergency Spill Reporting
(317) 241-4336

IDEM Community Right to Know Program Information
(317) 243-5176

Office of Indiana State Chemist (OISC)
Pesticide Section
Purdue University
1154 Biochemistry Bldg.
West Lafayette, IN 47907-1154
(317) 494-1587

State Board of Health (ISBH)
Division of Sanitary Engineering
1330 W. Michigan St.
P.O. Box 1964
Indianapolis, IN 46206-1964
(317) 633-0175

Cooperative Extension Service
Purdue University
Agricultural Extension Service
West Lafayette, IN 47907
(317) 494-8489

Michiana Area Council of Governments (MACOG)
1120 County City Bldg.
South Bend, IN 44601
(219) 287-1829

MICHIGAN

1. Key Groundwater Protection Issues

Groundwater Resources. Most of Michigan is endowed with plentiful groundwater resources and groundwater quality is generally high. Groundwater is particularly plentiful in thick deposits of glacial drift. However, there are localized contamination problems associated with landfills, leaking underground storage tanks, and manufacturing discharges. Naturally saline waters occur in eastern Michigan's shallow bedrock aquifers and locally elsewhere. Nitrate concentrations occur naturally in several areas of the state as well.

Groundwater Usage. Michigan's groundwater resources are used for a variety of purposes including domestic consumption, crop irrigation, food processing, industrial processes, and for cooling. Groundwater's substantial contribution to the water levels in rivers, lakes, and wetlands supports recreational uses, fisheries and wildlife habitat, and the overall quality of life in the state. Approximately half of Michigan's 9.4 million residents depend on groundwater for their sole source of drinking water. Public water consumption is the largest groundwater use, followed by self-supplied industrial use and rural domestic water supply.

Groundwater Contamination.

- As of 1992, Michigan has identified 3,396 sites of environmental contamination; 1,945 of these are known to have contaminated groundwater.
- There are an additional 5,000 identified sites of leaking underground storage tanks in the state.
- Several studies have found nitrate contamination of groundwater which is attributed primarily to agricultural practices.
- Industrial waste disposal into surface impoundments or injection wells is a major source of contamination in Michigan; in Kalamazoo county, more than half of the 65 contaminated sites are thought to have been caused by industrial waste disposal practices.

2. Groundwater Protection Programs

Legislation and Policies. The Michigan Water Resources Commission Act is the state's primary groundwater protection law and protects any aquifer suitable for supplying water for any reasonable use. The Michigan Environmental Response Act established the "Act 307 program" which monitors, prioritizes, and funds cleanup of the state's worst environmentally contaminated sites (Act 307 sites) and provides for public participation. Other relevant legislation includes: The Leaking Underground Storage Tank Act (1988); The Michigan Solid Waste Management Act (1978); and The Mineral Well Act (1969).

Program Elements. Michigan's Groundwater Protection Strategy and Implementation Plan, adopted in 1989, establishes the statewide approach for preventing and minimizing potential threats to groundwater quality. Implementation of the comprehensive groundwater management program involves the cooperative efforts of the Departments of Natural Resources (MDNR), Public Health (MDPH), State Police, and Agriculture (MDA). Selected elements of the state's program include:

- Development of a statewide groundwater data base as part of a growing natural resources geographic information system called the Michigan Resource Inventory System (MDNR).
- Development of a state wellhead protection program (MDNR and MDPH).
- In conjunction with a state groundwater vulnerability map, the Association of Soil Conservation Districts is developing county-based groundwater vulnerability maps based on soil data.
- Ongoing identification, assessment, and cleanup of environmentally contaminated Act 307 sites.
- The Public Water Supply Program provides supervision and testing of public water supplies and offers technical assistance (MDPH).
- The Waste Management Program regulates discharges of any wastewater to groundwater; solid waste disposal; and storage, treatment and disposal of hazardous waste (MDA).

Financial and Technical Assistance.

- Technical assistance is provided to communities developing their wellhead protection programs.
- A guidebook for local officials was developed on *Community Planning and Zoning for Groundwater Protection in Michigan.*

Public Education.

- The Michigan Departments of Education and Natural Resources are considering adoption of an Environmental Education Policy.
- The Michigan Department of Natural Resources and six state universities are sponsoring the 46th annual Higgins Lake Environmental School which promotes better understanding of humans and their environment.
- State agencies are working with the Groundwater Education in Michigan (GEM) program to promote better understanding of groundwater resources and how to protect them.

3. Key Agency Contacts

Michigan Department of Natural Resources (MDNR)
Office of Water Resources
P.O. Box 30028
Lansing, MI 48909
(517) 373-0014

Waste Management Division
P.O. Box 30241
Lansing, MI 48909
(517) 373-2730

Michigan Department of Public Health (MDPH)
Division of Water Supply
P.O. Box 30035
Lansing, MI 48909
(517) 335-9216

Michigan Department of Agriculture (MDA)
Pesticide and Plant Pest Management Division
P.O. Box 30017
Lansing, MI 48909
(517) 373-1087

Michigan Department of State Police (MSP)
Hazardous Materials Section - Fire Marshal Division
1150 Harris
Lansing, MI 48913
(517) 322-1953

1. Key Groundwater Protection Issues

Groundwater Resources. Within the Great Lakes Basin Minnesota has small to moderate groundwater supplies.

Groundwater Usage. More than two million people are served by public wells and one million people are served by private wells in Minnesota. There are approximately 11,000 public water supply systems using 17,000 wells. The state's 400 water well contractors construct between 7,000 and 12,000 wells annually.

Groundwater Contamination.

- Many of Minnesota's 40,000 large underground storage tanks are leaking.
- Of the 199 private and 395 public wells tested, 42 percent and 7 percent, respectively, have nitrate levels in excess of drinking water standards.
- Volatile organic compounds were found in 8 percent of the community water supply wells tested.
- More than 175 hazardous waste disposal sites in the state are classified as a priority for cleanup.
- Minnesota annually produces more than 95,000 tons of hazardous wastes.
- Between 300,000 and 370,000 abandoned wells have the potential to contaminate groundwater in the vicinity of municipal water supplies.
- More than fifty landfills are known to be polluting groundwater and are on Minnesota's priority state Superfund list.
- Saint Louis county, lying mostly within the Great Lakes Basin, has ten state Superfund sites; only two counties in the entire state have more.

2. Groundwater Protection Programs

Legislation and Policies. The 1989 Comprehensive Groundwater Protection Act sets a simple goal: "...that groundwater be maintained in its natural condition, free from any degradation caused by human activities." Taking a preventive approach, the Act incorporates recommendations of the state groundwater protection strategy and the companion strategy for the wise use of pesticides and nutrients. Other pertinent legislation includes the Minnesota Safe Drinking Water Act which provides authority for the Minnesota Department of Health (MDH) to establish maximum contaminant levels and to mandate frequency for monitoring of public water supply systems. The Metropolitan Surface Water Management Act of 1982 and the Comprehensive Local Water Management Act of 1985 are intended to foster state assisted, but locally coordinated, water resource planning and management.

Program Elements. Major groundwater protection program elements being implemented on a statewide basis include:

- Identification and detailed mapping of areas with high groundwater vulnerability. A state groundwater quality monitoring program will enhance previous water quality sampling efforts by providing more scientifically sound data from up to two thousand monitoring stations.
- Creation of fact sheets and guidance documents to promote understanding and compliance with statutes regulating the storage, handling, and disposal of pesticides.
- An Integrated Pest Management (IPM) program promoting IPM in the public and private sectors through education, technical or financial assistance, information and research.
- The state Environmental Quality Board, composed of citizens and heads of the major state environmental agencies, facilitates coordinated water management policies and activities.
- A wellhead protection program is being developed by the MDH.
- MDH also administers a program to ensure the proper construction and sealing of all wells and borings.

Financial and Technical Assistance.

- The state has set standards for establishing and maintaining individual sewage treatment systems. These standards are not mandatory but may be adapted for local ordinances. To assist with these local efforts, the Minnesota Pollution Control Agency offers training, certification, technical assistance, permitting, and grant funding throughout the state.
- Grants to counties fund preparation and implementation of "comprehensive local water plans," which include groundwater protection.
- A cost-sharing grant program for sealing improperly abandoned wells has been established with funds provided by the Groundwater Protection Act of 1989.
- Development of inventory guidebooks for local water plan implementation to ensure that local, county-coordinated inventories are compatible with the rest of the state.

Public Education.

- Establishment of state and regional environmental education resource centers serving as clearinghouses for environmental materials, as part of a major environmental education initiative.
- With the goal of integrating interdisciplinary environmental curriculum into all public elementary and secondary schools, Minnesota's Environmental Education Act became law in 1990.
- As part of an effort to improve communication between all levels of government, citizens and the private sector, Minnesota is developing a pilot electronic information system for sharing water-related information.

3. Key Agency Contacts

Minnesota Board of Water and Soil Resources (BWSR)
155 South Wabash, #104
St. Paul, MN 55107
(612) 296-3767

Minnesota Department of Natural Resources (DNR)
Waters Division
500 Lafayette Road North
St. Paul, MN 55146
(612) 296-4800

Minnesota Department of Agriculture (MDA)
90 West Plato Boulevard
St. Paul, MN 55107
(612) 297-2200

Minnesota Department of Health (MDH)
717 Delaware Street, S.E.
Minneapolis, MN 55440
(612) 623-5320

Minnesota Department of Health
Water Supply and Well Management Section
925 Delaware Street, S.E.
P.O. Box 9441
Minneapolis, MN 55459-0040
(612) 627-5170

Minnesota Geological Survey (MGS)
2642 University Avenue
St. Paul, MN 55114
(612) 627-4780

Minnesota Department of Education
Office of Environmental Education (OEE)
Capitol Square
550 Cedar Street
St. Paul, MN 55101
(612) 296-4055

Minnesota Pollution Control Agency (PCA)
520 Lafayette Road North
St. Paul, MN 55155
(612) 296-6300

Minnesota State Planning Agency (SPA)
EQB Water Resources Committee
300 Centennial Office Building
658 Cedar Street
St. Paul, MN 55155
(612) 296-9027

NEW YORK

1. Key Groundwater Protection Issues

Groundwater Resources. Within the Great Lakes Basin the quantity and quality of New York's groundwater resources are highly variable. The best groundwater supplies are provided by limestone and dolomite aquifers in the western region and local sand and gravel aquifers along streams. Areas of shale and crystalline rocks (of igneous and metamorphic origin) in the Adirondack region provide small yields. Saline water is a problem particularly along the lowland area south of Lake Ontario.

Groundwater Usage. Approximately three million upstate New Yorkers presently drink groundwater. Upstate New York has 18 "primary water supply aquifers" or present source aquifers for major municipal drinking water supplies. One sand and gravel aquifer, the Tug Hill Aquifer, extends for forty-seven miles through three counties (Jefferson, Oswego, Oneida) in northern New York, supplying water for more than 10,800 municipal water users and 3,700 private well users.

Groundwater Contamination. While upstate New York's groundwater is generally abundant and of good quality, groundwater contamination is a growing concern. Some critical examples include:

- Between 1982 and 1985, groundwater contamination by hazardous substances, particularly organic solvents and petroleum products, caused the closing of 33 wells in primary aquifers serving 17 public water supplies.
- Although well testing for groundwater contamination in upstate New York has been very limited, low concentrations of the pesticide aldicarb were found in 30 percent of the 76 wells sampled near treated fields.
- Many of upstate New York's urban and suburban areas with thousands of potential pollution sources are located directly over very vulnerable and critical water supply aquifers.
- Groundwater contamination along the Niagara River is among the worst cases in the U.S. Among the more than 215 hazardous waste sites in Erie and Niagara counties, those closer to the River contribute about 478 pounds of hazardous chemicals to the River.
- Spills and leaks of petroleum products, both past and present, pose a significant threat to groundwater.
- In 1987 it was estimated that 24,000 of New York's 110,000 underground storage tanks were leaking.
- More than 100 of New York's 420 municipal solid waste landfills are located over or adjacent to highly vulnerable aquifers and pose a serious threat to ground-water.

2. Groundwater Protection Programs

Legislation and Policies. There is no single piece of legislation that addresses groundwater protection in New York. However, the Groundwater Management Program of 1987 promotes groundwater prevention through a geographic or location-specific focus which includes the most high-yielding, highly used and/or most vulnerable aquifer systems.

Program Elements. Numerous state and federal agencies as well as county and town governments have important responsibilities in groundwater protection efforts. Primary authority for groundwater protection, however, is shared by two major state agencies, the Department of Environmental Conservation (DEC) and the Department of Health (DOH). Examples of New York's groundwater protection efforts include:

- The State Pollutant Discharge Elimination System (SPDES) program regulates municipal, industrial, and commercial wastewater discharges including discharges to groundwater.
- Establishment of groundwater aquifer classifications and quality standards help to prevent groundwater contamination and prioritize the most important aquifer systems.
- Geographic targeting of groundwater management efforts allow emphasis to be placed on critical areas such as recharge areas, municipal wellheads, primary drinking supply aquifers, and aquifers susceptible to overdevelopment.
- Nonpoint source management plan.
- Water pollution control permitting.

- Hazardous waste and pesticide regulation.
- Municipal level watershed rules and regulations.

Financial and Technical Assistance.

- Cornell Pesticide Applicator Education Program trains pesticide applicators for certification, disseminates information, and monitors pesticide-related issues.
- Regional planning agencies in many areas of New York provide technical assistance and consultation to local and county governments.
- Several towns are currently receiving assistance to develop wellhead protection plans.
- New York State Water Resource Institute (WRI) and Cornell Cooperative Extension provide technical assistance to a various communities and agencies around the state.

Public Education.

- Cornell Cooperative Extension (CCE) has educational materials and programs aimed at general groundwater and well protection issues.
- WRI and CCE provide training and materials to county agents about groundwater protection and data management.

3. Key Agency Contacts

Department of Environmental Conservation (DEC)
Division of Water
50 Wolf Road, Room 310
Albany, NY 12233
(518) 457-6674

Contact the DEC for information pertaining to:

- enforcement of legislation pertaining to groundwater
- groundwater mapping
- well protection
- sole source aquifer program

Department of Health (DOH)
2 University Place
Albany, NY 12203-3313
(518) 458-6731

Contact the DOH for information pertaining to:

- public water supply quality and protection
- watershed rules and regulations
- regulation of water companies

Water Resources Institute
115 Wing Hall
Cornell University
Ithaca, NY 14853-8101
(607) 255-5941

Cornell Cooperative Extension Resources
Resource Center
7 Business and Technology Center
Ithaca, NY 14850
(607) 255-2080

OHIO

1. Key Groundwater Protection Issues

Groundwater Resources. Ohio's moderate supply of groundwater is provided by both bedrock and unconsolidated (loosely held together) aquifers. Unconsolidated aquifers occur more along the Basin boundary; carbonate (formed with calcium carbonate or limestone) and sandstone aquifers occur in the western and eastern portions of the state, respectively. Generally, groundwater quality is of greater concern than quantity; naturally occurring dissolved solids generally occur at high concentrations.

Groundwater Usage. Aquifers occur throughout Ohio and the cities of Dayton, Canton, and Springfield are entirely dependent on groundwater supplies. About 75 percent of Ohio's 1,600 community water supplies depend on groundwater for some part of their water supply. Industry uses about 350 million gallons of groundwater per day and agricultural irrigation uses about 10 million gallons per day.

Groundwater Contamination.

- In 1992, 32 hazardous waste sites in Ohio qualified for top priority cleanup under the Superfund program and more than 1,000 additional sites need further investigation to determine if cleanup is necessary.

- As a preventive measure, 90 hazardous waste sites in Ohio are required to do ongoing groundwater monitoring.
- In 1992, Ohio had 96 licensed landfills and 24 captive industrial facilities. Based on new regulatory requirements, many of the facilities are establishing groundwater protection measures and assessing groundwater quality impacts.
- Up to a third (based on national average) of Ohio's 75,000 to 80,000 underground storage tanks may be leaking. These numbers do not include motor fuel tanks, on-site heating oil storage tanks, and septic tanks which are exempt from the State Fire Marshal's reporting requirements.
- There are more than one million permanent homes relying on septic tanks.
- Reclamation efforts continue on Ohio's 400,000 acres of abandoned mine lands which present an ongoing threat to groundwater quality in the eastern half of the state.
- As a liquid by-product of oil and gas production, Ohio produces at least 40,000 to 50,000 barrels of brine daily which are disposed of through underground injection and road spreading.
- In 1979, Ohio EPA identified 2,700 wastewater impoundments and lagoons that store, treat, and dispose of industrial, municipal and agricultural wastewaters; no thorough site inspections on regular basis are conducted.
- There are literally thousands of shallow wells in Ohio receiving various fluids that pose a serious threat to groundwater quality. These are Class V injection wells, which may direct wastewaters into underground sources of drinking water. More than 300 million gallons of liquid waste, much of which is designated as hazardous, are disposed of in deep injection wells (Class I) in Ohio. While none of the Class I wells have caused groundwater contamination, proper operation, maintenance and regulatory oversight is imperative to protect groundwater.

2. Groundwater Protection Programs

Legislation and Policies. Ohio's groundwater protection policy is defined in the 1986 Groundwater Protection and Management Strategy.

Program Elements.

- Ongoing investigation and remediation of hazardous waste sites and closed landfills.
- Identifying and improving vulnerable public water supplies.
- Research and documentation of site-specific surface/groundwater interconnections.
- Under Ohio's Wellhead Protection Program, drinking water system owners and operators are developing and implementing local wellhead protection plans with the technical assistance and approval of the Ohio EPA.
- One of Ohio's four designated sole source aquifers, the Catawaba Island Aquifer, is located within the Great Lakes Basin and receives special protection under the federal Safe Drinking Water Act.

Financial and Technical Assistance.

- Ohio's Pollution Control Loan offers low interest loans for communities to improve water quality and public health. While most of the $71 million loaned to 20 communities in 1990 went toward wastewater treatment technology, monies are also available for groundwater pollution control.
- Ohio EPA's Division of Environmental and Financial Assistance is providing technical assistance to progress-oriented, small communities with high economic need.
- Ohio Water Development Authorization.

Public Education.

- The Ohio EPA established the Ohio Environmental Education Fund in October 1990 to enhance public awareness and objective understanding of environmental issues in Ohio. Monies credited to the Fund consist of one-half of all civil penalties collected by the Ohio EPA air and water pollution control programs, as well as gifts, grants and contributions. The Fund offers two types of grants: mini-grants for projects totaling $5,000 or less, and regular grants for projects ranging from $5,000 to $50,000. To date, the Fund has awarded $1.3 million in grants. Recipients are highly diversified – classroom teachers, college professors, nonprofit organizations, trade associations and government agencies. Currently, two projects have been funded that solely target groundwater education. The first is a campaign to increase public awareness of groundwater issues in the Village of Canal Winchester, Ohio. The second is a project designed by the Miami Valley Regional Planning Commission, a consortium of regional governments in southwest Ohio. The Commission will use findings presented in its 1990 Groundwater Protection Strategy to educate water purveyors, local governments, business and industry, and citizen groups on effective regional groundwater protection techniques.

3. Key Agency Contacts

Ohio Environmental Protection Agency (EPA)
Division of Drinking and Groundwaters
1800 WaterMark Drive
P.O. Box 1049
Columbus, OH 43266-0149
(614) 644-2160

Water quality monitoring, planning standards; public water supply; spill response; solid and hazardous waste disposal; nonpoint source pollution; laboratory support; wastewater treatment plants; Ohio Environmental Education Fund.

Ohio Department of Natural Resources (ODNR)
Fountain Square
Columbus, OH 43224
(614) 265-6789

Contact ODNR for:

Water planning; oil/gas/brine production and disposal; mining and reclamation; groundwave resource assessments; groundwater well logs; recycling; laboratory support; geologic maps: groundwater conflict resolution and investigation; designation of groundwater stress areas; groundwater pollution potential mapping.

Ohio Department of Health (ODH)
246 North High Street
P.O. Box 118
Columbus, OH 43266-0588
(614) 644-8562

Contact ODH for:

Health effects from contamination; regulation of private well construction and individual wastewater disposal systems; laboratory support.

Public Utilities Commission of Ohio (PUCO)
180 East Broad Street
Columbus, OH 43266-0302
1-800-282-0198

Contact PUCO for:

Hazardous waste transportation.

Ohio Department of Agriculture (ODA)
Ohio Departments Building
65 South Front Street, 6th Floor
Columbus, OH 43266-0302
(614) 466-8798

Contact ODA for:

Pesticides regulations; laboratory support.

Bureau of Underground Storage Tanks
7510 E. Main Street
Reynoldsburg, OH 43068
(614) 752-7938

ONTARIO

1. Key Groundwater Protection Issues

Groundwater Resources. Groundwater is used by approximately one-third of Ontario's population for a variety of municipal, industrial and agricultural activities. The demand for the resource continues to grow at an exponential rate as development moves into rural areas. The province generally has adequate supplies of groundwater. The availability of groundwater is of little benefit if its quality cannot be assured. Ontario's groundwater is susceptible to contamination from both point and nonpoint sources, as demonstrated by a number of recent problems.

Groundwater Usage. In 1981, almost one-fourth of all Ontario's municipal, domestic, and rural water users relied on groundwater. Ontario's estimated largest users are municipal water users, followed by rural, agricultural, and then industrial users.

Groundwater Contamination. The following information is indicative of groundwater contamination problems which are being documented in Ontario:

- As more development moves into sensitive aquifer areas, increased groundwater contamination from private septic systems poses a major challenge for Ontario.
- The costs of remediation of contamination from de-icing salts are growing at an increasing rate.
- Underground storage tanks are still a major source of contamination.
- Hazardous material spills cost the province millions of dollars, yet can only be controlled and not cleaned up.

2. Groundwater Protection Programs

Legislation and Policies. The following legislation, policies and guidelines serve to protect and manage groundwater in the province of Ontario: Ontario Water Resources Act; The Environmental Protection Act; The Pesticides Act; The Health Protection and Promotion Act; The Gasoline Handling Act; The Petroleum Resources Act; Ontario Regulation 612/84;

Program Elements. Ontario's Ministry of Environment (OMOE) is in the process of developing a Groundwater Management and Protection Program. The program is intended to address several issues including: contaminant impact assessment, water well management, aquifer mapping, public information and education, and research. Groundwater resources in Ontario, are however, currently being managed and protected by multi-jurisdictional legislation.

3. Key Agency Contacts

Ontario Ministry of the Environment (MOE)
Water Resources Branch
135 St. Clair Avenue West
Toronto, Ontario M4V 1P5
(416) 323-4941

Northwestern Region, Thunder Bay	(807) 475-1205
Northeastern Region, Sudbury	(705) 675-4501
Southeastern Region, Kingston	(613) 549-4000
West Central Region, Hamilton	(416) 521-7640
Central Region, Toronto	(416) 424-3000
Southwestern Region	(519) 661-2200

Ontario Ministry of Agriculture and Foods (AF)
Resources Management Branch
Guelph Agriculture Center
P.O. Box 1030
Guelph, Ontario N1H 6N1
(519) 767-3561

Ontario Ministry of Natural Resources (OMNR)
Water Resources Branch
1 St. Clair Avenue West - 4th Floor
Toronto, Ontario M4V 1K6
(416) 323-4941

Approvals Branch
(416) 440-3713

Waste Management Branch
(416) 323-5200

Public Affairs & Communications Services Branch – Public Information Centre
(416) 323-4321

Government Documents Requests – Spills Action Centre
(416) 325-3000

1. Key Groundwater Protection Issues

Groundwater Resources. The 603 square miles of Pennsylvania lying within the Great Lakes Basin contains small to moderate supplies of groundwater. The best opportunities for groundwater development are along perennial (continually flowing) streams in thick, unconsolidated materials where induced recharge is possible. Groundwater quality is mostly of concern in the region's bedrock aquifers.

Groundwater Usage. Nearly half of Pennsylvania's residents depend on groundwater for their drinking water needs. In rural areas, groundwater is the only practical source of water for domestic uses.

Groundwater Contamination. Leaking underground storage tanks are considered Pennsylvania's major source of groundwater contamination. Other sources include coal mining (abandoned and active sites), bulk storage tanks, chemical plants, and oil and gas exploration activities.

2. Groundwater Protection Programs

Legislation and Policies. Pennsylvania's Groundwater Quality Protection Strategy defines the state's groundwater protection policy. The ultimate goal of the groundwater protection strategy is nondegradation of groundwater quality. The Pennsylvania Clean Streams Law and the Solid Waste Management Act mandate the conservation and protection of groundwater. Other legislation protecting groundwater quality includes: Surface Mining Conservation and Recovery Act, Coal Refuse Disposal Control Act, Oil and Gas Act, Safe Drinking Water Act, Water Well Drillers Licensing Act, Storm Water Management Act, Storage Tank and Spill Prevention Act, Hazardous Sites Cleanup Act, and Pesticide Control Act. All of these Acts are implemented by the Pennsylvania Department of Environmental Resources (DER).

Program Elements.

- A limestone aquifer in the Piedmont Region is a designated sole source aquifer protected under the U.S. Safe Drinking Water Act.
- Developing vulnerability assessments of wellhead recharge areas to regulate land use.
- Identifying well water sources susceptible to surface water contamination.
- Pennsylvania Coastal Zone Management Program.
- Ambient groundwater quality monitoring in selected basins.
- Groundwater pollution incident investigations.
- Development of comprehensive statewide groundwater quality management program.
- Identification of areas of special groundwater concern.
- Develop and update guidance on groundwater impact activities (e.g., land application of wastes, groundwater heat pumps).

Financial and Technical Assistance.

- Grants in 1991 for municipal wellhead protection pilot programs will provide information for the development of Pennsylvania's wellhead protection program.

Public Education.

- The Water Conservation/Technical Assistance Section of the DER, offers technical assistance on water conservation as well as displays, films/videocassettes, slide presentations, and classroom-ready curriculum for public schools.
- Local government workshops on wellhead protection are conducted by the DER Bureau of Community Environmental Control.

- The DER Bureau of Soil and Water Conservation's Mobile Nutrients Lab provides outreach to farmers and rural residents on a variety of water- and soil-related topics, including groundwater protection.
- The Bureau of State Parks Environmental Education and Interpretive Section offers an environmental education curriculum for schools, as well as interpretive programs in parks, and outreach programs.
- The DER Public Liaison Office develops educational materials, displays, and information referral for the general public.
- The Office of Environmental Education in the Department of Education provides teacher training and teacher resource information.
- The PA Groundwater Policy Education Project (a project of Penn State Extension, League of Women Voters, and the DER) promotes local policy and education activities throughout Pennsylvania.

3. Key Agency Contacts

Pennsylvania Department of Environmental Resources
Bureau of Water Resources Management
Water Resources and Technical Assistance Information Section
P.O. Box 8761
Harrisburg, PA 17105-8761
(717) 541-7805

Bureau of Water Quality Management
P.O. Box 2063
Harrisburg, PA 17105-2063
(717) 787-9633

Bureau of Community Environmental Control
Division of Water Supplies
P.O. Box 2357
Harrisburg, PA 17105-2357
(717) 787-9037

Office of Public Liaison
P.O. Box 2063
Harrisburg, PA 17105-2063
(717) 783-7005

Pennsylvania Office of Environmental Education
Department of Education
333 Market Street, 8th Floor
Harrisburg, PA 17126-0333
(717) 783-6994

Pennsylvania Groundwater Policy Education Project
The Pennsylvania State University
2 Weaver Building
University Park, PA 16802-5502
(814) 865-2561

WISCONSIN

1. Key Groundwater Protection Issues

Groundwater Resources. Within the Great Lakes Basin, Wisconsin's groundwater resources are highly variable. Wisconsin has four primary aquifer types including sand and gravel aquifers, dolomite aquifers, sandstone aquifers, and deep crystalline bedrock aquifers. The sand and gravel aquifers which cover most of the state in variable thickness provide high yields in the northwest. Water quality is generally excellent in shallow aquifers but declines with depth and to the east.

Groundwater Usage. An estimated 570 million gallons of groundwater supply nearly one-third of Wisconsin's business and industrial uses and three-fourths of Wisconsin's residential water needs. In addition, there are an estimated 700,000 private wells in the state.

Groundwater Contamination.

- An estimated 2,700 known abandoned dumps and countless other unknown dumps continue to leach contaminants into the state's groundwater.
- The pesticide atrazine, a suspected cancer-causing chemical, was found in 66 of 534 wells tested in 1989.
- Wisconsin ranks eighth in the nation with 32 hazardous waste contamination sites that have qualified for federal Superfund cleanup funds. An additional 300 sites in the state are up for consideration.

- Thousands of Wisconsin's 140,000 underground storage tanks have caused groundwater contamination and many more are discovered each year.

2. Groundwater Protection Programs

Legislation and Policies. Wisconsin's comprehensive Groundwater Protection Act of 1984 is used by all state agencies to regulate activities with groundwater contamination potential.

Program Elements. Wisconsin's Groundwater Coordinating Council (GCC), consisting of representative from all of the groundwater-related state agencies, coordinates and guides groundwater protection efforts under the statewide management program. The agencies (see Key Contacts below) fund groundwater research, monitor groundwater, evaluate and establish groundwater policies and standards, coordinate groundwater information management and exchange, and do public outreach. Specific program elements include:

- "Clean Sweep" toxic waste collection days for community household hazardous waste.
- Regulatory standards established for every substance already found in groundwater and those with a high potential to reach groundwater.
- A Groundwater Information Network (GIN) which facilitates the management and sharing of groundwater information on a standardized computer system.
- Major groundwater research efforts coordinated by the University of Wisconsin Groundwater Research Advisory Council.

Financial and Technical Assistance.

- A technical bulletin titled "Best Management Practices for Wisconsin Farms."
- Groundwater monitoring and technical assistance for new landfill design and wastewater treatment.

Public Education.

- Groundwater demonstrations, lectures, and seminars at the county and state levels.
- Classroom-ready curriculum materials on groundwater education for K-12 public and private schools.
- Special publication, "Groundwater: Protecting Wisconsin's Buried Treasure," a special to the *Wisconsin Natural Resources* magazine.

3. Key Agency Contacts

Wisconsin Department of Natural Resources (DNR)
Ground Water Management Section
P.O. Box 7921
Madison, WI 48909
(608) 267-9350

Wisconsin DNR District Offices

North Central	(715) 362-7616
Northwest	(715) 635-2101
Western	(715) 839-3700
Lake Michigan	(414) 497-4040
Southeast	(414) 562-9500
Southern	(608) 275-3266

Contact the DNR for information about:

- Sewage lagoons, municipal and industrial wastewater systems
- Landfills, hazardous waste disposal
- Mining
- Spill response
- Public drinking water systems
- Well drilling
- Water quality planning
- Drinking water standards
- Groundwater monitoring, well water sampling
- State groundwater quality standards

Wisconsin Geological and Natural History Survey (WGNHS)
3817 Mineral Point Road
Madison, WI 53705
(608) 262-1705

Contact WGNHS for:

- Maps and inventories of groundwater resources and geologic formations
- Technical reports

- Groundwater levels and water quality monitoring information
- Education materials

Department of Industry, Labor and Human Relations (DILHR)
Office of Division Codes & Applications
P.O. Box 7969
Madison, WI 53707
(608) 266-3131

Contact DILHR for information about:

- Inspections and records on underground storage tanks
- Septic system regulations
- Home water treatment devices
- Education materials

Department of Agriculture, Trade and Consumer Protection (DATCP)
801 W. Badger Road
Madison, WI 53708
(608) 273-6400

Contact DATCP for information about:

- Use of pesticides
- Fertilizer and pesticide storage facilities inspections
- Inspection of water supplies of food processors and Grade-A dairy farms
- Water bottlers licensing
- Education materials

Central Wisconsin Groundwater Center (CWGC)
Room 010, Student Services Center
University of Wisconsin-Stevens Point
Stevens Point, WI 54481

Contact CWGC and University of Wisconsin Cooperative Extension (UWEX) County Offices for information about:

- Education
- Outreach
- Private well testing (CGWC)

D. ACADEMIC AND NON-GOVERNMENTAL INSTITUTIONS

It is beyond the scope of this guidebook to provide contact information for all of the academic and non-governmental organizations that may contribute to groundwater protection in the Great Lakes region. Tips are provided for maximizing your use of the region's academic institutions. In addition this section highlights the Great Lakes Sea Grant program and selected non-governmental institutions.

UNIVERSITIES/COLLEGES

Many universities and colleges have academic programs that deal with critical aspects of groundwater protection. Relevant programs may fall under a variety of titles but provide similar expertise and resources. When contacting academic institutions, use the following table to assist you in locating the department(s) most closely related to your informational needs.

Department, Area(s) of Expertise

Natural Resources/Forestry/Environmental Sciences: waste management, policy issues, public outreach, soil science, water quality/testing, agronomy, negotiation/dispute resolution

Geology/Earth Science: hydrogeology, geology, hydrology, geographic information system (GIS)

Public Health: toxicology, epidemiology, pubic policy

Environmental Engineering: environmental computer modeling, hazardous waste management, landfill design

Urban Planning: land use planning, site assessment

In addition to expert opinions/consulting, these departments may be able to provide access to: maps of soil, groundwater, topography, land use; bibliographical resources such as technical and policy guides; key community/governmental contacts; and research equipment (e.g., water quality testing kits). University students are sometimes eager to assist in real world community issues. University and college departments in your jurisdiction can be located using the phone book or directory assistance.

OTHER INSTITUTIONS

Environmental Councils

The Illinois, Hoosier, Michigan and Ohio Environmental Councils are involved in a Great Lakes Citizens' Groundwater Protection Project. The Environmental Councils are representative of environmental and conservation organizations in the four-state area. Member organizations unite to protect and enhance the region's human and natural environment and to ensure its sustainability. The Councils act through networking, advocacy, education and research to achieve their goals.

The major focus of the Great Lakes Citizens' Groundwater Protection Project is to improve the effectiveness of citizen leaders in addressing groundwater concerns by forming citizen leadership teams for each state. The teams will help create state groundwater contamination "profiles," case studies of successful citizen involvement in groundwater protection, and videotapes. For more information, contact:

Illinois Environmental Council
1001 South Wright St.
Champaign, Illinois 61820
217/384-0830.

Hoosier Environmental Council
1002 E. Washington,Suite 300
Indianapolis, Indiana 46202
317/685-8800.

Michigan Environmental Council
115 W. Allegan, Suite 10B
Lansing, Michigan 48933
517/487-9539.

Ohio Environmental Council
400 Dublin Ave., Suite 120
Columbus, Ohio 43215-2333
614/224-4900.

Environmental Defense Fund

The Environmental Defense Fund (EDF) is a national non-profit research, education, and advocacy organization founded in 1967. EDF has more than 200,000 members with offices in New York (headquarters); Washington, DC; North Carolina; Texas; Colorado; and California. EDF scientists, economists, and attorneys work to develop positive solutions to complex environmental problems.

EDF's Pollution Prevention Alliance (PPA) works with local, state and regional organizations in the Great Lakes states to promote pollution prevention and sustainable communities. PPA establishes collaborative projects among organizations at many levels to protect groundwater from toxic contamination through pollution prevention. For example, EDF staff and local environmental organizations in several Great Lakes communities are developing partnerships with diverse citizens groups, government, and business groups to promote pollution prevention in small and medium-sized businesses whose use of toxic substances may pollute groundwater.

The Alliance is centered in the Great Lakes region for three reasons. First, although the eight states that border on the Great Lakes share a regional identity, their environmental protection efforts are largely independent of each other. The PPA program and network provide a means of integrating the efforts of the region's grassroots and state-level activists. In this way, the Alliance strengthens the cause of individual organizations while harnessing their resources to affect change on a broader level than they might otherwise reach. Second, the Great Lakes region is a delicate ecosystem, desperately in need of protection. It is home to 95 percent of the nation's fresh water, a sizable portion of the U.S. population, and many industrial, commercial, and agricultural polluters. Third, the PPA program serves as a surrogate midwestern office for EDF since EDF has no office in that area of the country.

For more information, contact:

Environmental Defense Fund
1875 Connecticut Ave., Suite 1016
Washington D.C. 20009
202/387-3500

Freshwater Foundation

The Freshwater Foundation is a non-profit organization that serves as a catalyst to promote actions and activities that sustain, support, and improve freshwater policy and management. Freshwater pursues the protection of freshwater resources through educational programs, resource management, demonstration projects and research.

Freshwater's projects focus on the Foundation's four areas of focus: water education, surface and groundwater management, water policy and water and health. Examples include: The Great Lakes Groundwater Management System, Lakewatch, the Health and Environment Digest and co-publication of U.S. Water News.

The Foundation, whose goal is to serve the nation, is supported by membership dues, annual gifts and project grants.

A unique information network, known as the Groundwater Information System (GWIS), is being designed to address groundwater issues in the Great Lakes region. Serving as a groundwater information source for people in the region and encouraging coordinated policy development is the focus of GWIS. A regional steering committee is being formed to enhance communication among regional groups and identify and develop leadership at the local level.

For more information, contact:

The Freshwater Foundation
Springhill Center
725 County Rd. 6
Wayzata, Minnesota
612/449-0092.

Great Lakes Sea Grant Programs

Through research, education, and extension, the Sea Grant Program helps individuals, local communities, businesses, and state and local agencies to wisely develop, protect, and use the resources of the Great Lakes. The Programs are funded by the National Sea Grant College Program, a branch of the National Oceanic and Atmospheric Administration (NOAA). These funds are supplemented by matching funds from the state, universities, businesses, and other non-federal sources. The Great Lakes Sea Grant Network includes the programs in Illinois/Indiana, Michigan, Minnesota, New York, Ohio and Wisconsin.

A Sea Grant/4-H Extension Agent provides Great Lakes curricula and special educational programming such as field trips for public school students. Sea Grant Extension facilitates the link between researchers and residents, businesses, agencies, and others who need information and assistance.

Contact the Sea Grant Program in your jurisdiction to find out more about their programs and the education opportunities which Sea Grant has to offer. Program contacts are listed below by jurisdiction.

Sea Grant Contacts

Illinois-Indiana Sea Grant Program
University of Illinois
65 Mumford Hall
1301 W. Gregory Drive
Urbana, IL 61801
(217) 333-9448

Michigan Sea Grant College Program
University of Michigan
2200 Bonisteel Boulevard
Ann Arbor, MI 48109
(313) 764-1138

Minnesota Sea Grant College Program
University of Minnesota
1518 Cleveland Avenue, W, Suite 302
St. Paul, MN 55108
(612) 625-9790

New York Sea Grant
SUNY at Stony Brook
Dutchess Hall
Stony Brook, NY 11794-5001
(516) 632-6905

Ohio Sea Grant College Program
The Ohio State University
1314 Kinnear Road
Columbus, OH 43212-1194
(614) 292-8949

Wisconsin Sea Grant Institute
University of Wisconsin-Madison
1800 University Avenue
Madison, WI 53705
(608) 263-5371

Groundwater Education in Michigan

The Groundwater Education in Michigan (GEM) Program is a collaborative groundwater education effort by Michigan State University's Institute of Water Research (IWR), the W.K. Kellogg Foundation and a network of community based organizations. The GEM program started in Michigan and has now expanded to include all of the Great Lakes states and provinces.

The GEM program solicits creative ideas for groundwater protection efforts and offers assistance to environmental organizations, planning and health associations and others. Institute of Water Research and GEM staff offer a variety of services including: assistance in developing program strategies for community groundwater protection and education activities; assistance in identifying funding sources, including grants available through the Kellogg Foundation's water resources programming area and other sources of financial resources; hands-on technical assistance to local communities; information exchange through GEMNET, a computer communications system (Call the GEMNET hotline at 1-800-962-9571); and educational resources and materials provided at a nominal cost.

For more information or assistance, contact:

The Groundwater Education in Michigan (GEM) Program
Institute of Water Research
334 Natural Resources Building
Michigan State University
East Lansing, MI 48824
(517) 353-3742

Heidelberg College - Water Quality Laboratory

The Water Quality Laboratory (WQL) is a research organization associated with the science departments of Heidelberg College in Tiffin, Ohio. The WQL's research programs focus on studies of the impacts of agricultural land use on water quality. The WQL maintains a modern highly automated analytical laboratory that is used for its well testing and river monitoring programs.

The WQL has established a cooperative well testing program designed to support local groundwater education and protection by combining locally sponsored private well testing programs with the development of detailed local data bases on rural drinking water quality. Cooperating groups include local sponsoring organizations, county residents who select to have their wells tested as part of the program and the WQL.

Individuals receive a report listing concentrations of tested chemicals in their water supply and the related safe drinking water standards. Local organizations receive county summaries, maps and color slides depicting rural drinking water quality.

For more information, contact:

Cooperative Well Testing Program
Water Quality Laboratory
Heidelberg College
310 E. Market St.
Tiffin, Ohio, 44883
419/448-2201.

League of Women Voters of Pennsylvania Citizen Education Fund (LWVCEF) and Pennsylvania State University Cooperative Extension Service (CES)

These two organizations have teamed up to provide information and technical tools needed for groundwater protection activities at the local level. Regional training workshops are being conducted to improve leadership development among citizens and public officials. Opportunities

are also available for those leaders to work with others in their communities to implement local groundwater management and protection programs. This includes financial and technical support for local groups conducting model local groundwater policy education projects.

For more information, contact:

LWVCEF
RD 1
Cresco, Pennsylvania 18326
717/839-8130.

Pennsylvania State University
College of Agriculture
2 Weaver Bldg.
University Park, Pennsylvania 16802
814/865-2561.

Michigan Geographic Alliance (MGA)

The Michigan Geographic Alliance is a network of teachers and geographers organized to use geography to improve the education of Michigan's children. The primary mission of the Alliance is to provide high quality, low cost geographic in-service presentations to teachers. major projects of the Geographic Alliance include environmental projects, particularly associated with the Great Lakes, the Family Geography Project, a teacher exchange project with the Dominican Republic, and work on geography standards associated with the nation's education goals. The Alliance provides geographic training and support for a group of 100 Alliance teacher consultants to work with other teachers.

The Michigan Geographic Alliance is an externally funded program of Central Michigan University. It is one of 50 state Geographic Alliances coordinated by the National Geographic Society Education Division. The Michigan Geographic Alliance is supported by the National Geographic Society Education Division. The Michigan Geographic Alliance is supported by the National Geographic Society Education Foundation, the State of Michigan, foundations and corporations.

Educators and groundwater specialists are currently coordinating efforts to integrate groundwater lessons into upper elementary geography curriculum in the eight Great Lakes states. The Alliance has hosted a regional conference and follow-up meetings at which participants were trained about groundwater concepts and helped to develop a geography unit on groundwater. These educators are committed to training teachers in their state to use the materials in their classrooms.

For more information, contact:

Michigan Geographic Alliance
Central Michigan University
Department of Geography
Mt. Pleasant, Michigan 48859
517/774-3723.

Chapter 8

GROUNDWATER BIBLIOGRAPHY- Available Resources and Literature

An abundance of important resource materials and publications are available for educators, citizens, government officials and everyone interested in learning more about groundwater resources and their protection. However, it is sometimes difficult to find the right reference for your specific interest among all these publications.

In particular, two groundwater reference guides are especially useful. Teachers will find *Ground Water Education in America's Schools: A Catalog of Resource Materials for Elementary and Secondary Education Professionals* (1990) an excellent annotated bibliography of the wealth of available groundwater curriculum materials. Prepared by The American Ground Water Trust, it is available from them at 6375 Riverside Drive, Dublin, Ohio 43017, (614) 761-2215.

For general interest, readers should refer to *Groundwater Reference Guide: An Annotated Bibliography of Publications Related to Groundwater Protection* (1991). Prepared by the Groundwater Education in Michigan (GEM) program, this 25-page booklet is a concise, well-organized guide to some of the best references covering a broad spectrum of groundwater topics. It is available from GEM, Institute of Water Research, 334 Natural Resources Building, Michigan State University, East Lansing, Michigan 48824-1222, (517) 353-3742.

This Chapter provides a bibliography of available groundwater resource materials organized alphabetically in the following categories: federal publications; state/provincial publications; other (miscellaneous) publications; and educational materials. Chapter 4 provides the phone numbers and addresses of many of the issuing agencies and organizations where these publications can be ordered. For more assistance in finding these resources contact the Great Lakes Commission at (313) 665-9135.

A. FEDERAL PUBLICATIONS

United States

Heath, Ralph C., 1989. *Basic Ground Water Hydrology.* Water Supply Paper 2220. U.S. Geological Survey.

Heath, Ralph C., 1984. *Ground-Water Regions of the United States.* Geological Survey Water Supply Paper 2242. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 78p.

Merk, Charles F., Robert R. Pierce, and Wayne B. Solley, 1988. *Estimated Use of Water in the United States in 1985.* U.S. Geological Survey, Circular 1004.

Royal Society of Canada and National Research Council of the United States, 1985. *The Great Lakes Water Quality Agreement: An Evolving Instrument for Ecosystem Management.* Royal Society, Ottawa, and National Research Council, Washington, D.C.

U.S. Army Corps of Engineers, 1987. *Emergency Water Plan Inventory-State of Michigan.* Detroit, MI. U.S. Army Corps of Engineers.

U.S. Army Corps of Engineers, 1986. *Prototype Emergency Water Plan, Bay-Midland-Saginaw Counties, Michigan.* Detroit, MI. U.S. Army Corps of Engineers.

U.S. Department of the Interior, 1987. *Regional Aquifer System Analysis Program of the U.S. Geological Survey: Summary of Projects, 1978-84.* U.S. Geological Survey, Circular 1002. Free on application to Books and Open-File Reports Section, U.S. Geological Survey. 264p.

U.S. Environmental Protection Agency, Ground-Water Protection Division, 1991. *A Review of Methods for Assessing Nonpoint Source Contaminated Ground-Water Discharge to Surface Water.* EPA 570/9-91-010.

U.S. Environmental Protection Agency, Ground-Water Protection Division, 1990. *Citizen's Guide to Ground-Water Protection.* EPA 440/6-90-004.

U.S. Environmental Protection Agency, Ground-Water Protection Division, 1990. *Guide to Ground-Water Supply Contingency Planning for Local and State Governments: Technical Assistance Document.* EPA 440/6-90-003.

U.S. Environmental Protection Agency, Ground-Water Protection Division, 1990. *Hydrogeologic Mapping Needs for Ground-Water Protection and Management: Workshop Report.* EPA 440/6-90-002.

U.S. Environmental Protection Agency, Ground-Water Protection Division, 1990. *Protecting the Nation's Ground-Water: EPA's Strategy for the 1990's.* EPA 21Z/1020.

U.S. Environmental Protection Agency, Ground-Water Protection Division, 1989. *Funding of Ground-Water Protection: Quick Reference to Grants Available Under the Clean Water Act.* EPA 440/6-89-004.

U.S. Environmental Protection Agency, Ground-Water Protection Division, 1986. *Guidelines for Ground-Water Classification under the EPA Ground-Water Protection Strategy.* Final Draft. EPA 440/6-84-002.

U.S. Environmental Protection Agency, Ground-Water Protection Division, 1986. *Septic Systems and Ground-Water Protection: A Program Manager's Guide and Reference Book.* EPA 440/6-86-006.

U.S. Environmental Protection Agency, Ground-Water Protection Division, 1986. *Septic Systems and Ground-Water Protection: An Executive's Guide.* EPA 440/6-86-005.

U.S. Environmental Protection Agency, Office of Research and Development, 1990. *Ground Water and Contamination Handbook.* Ground Water, Vol. I. EPA 625/6-90/016a.

U.S. Environmental Protection Agency, Office of Water, 1989. *Local Financing for Wellhead Protection.* EPA 440/6-89-001. 55p.

U.S. Environmental Protection Agency, Office of Water, Office of Ground Water Protection, 1990. *Progress in Ground-Water Protection and Restoration.* EPA 440/6-90-001. 78p.

U.S. General Accounting Office, 1988. *Groundwater Protection: The Use of Drinking Water Standards by the States.*

Waller, Roger M., 1988. *Ground Water and the Rural Homeowner.* U.S. Geological Survey.

Warner, Kelley L., John D. Earle, and Marvin G. Sherrill, 1991. *Hydrogeologic Information in the Great Lakes Basin, United States, and Application of a Geographic Information System to Public-Supply Wells and Hazardous-Waste Sites.* Open-File Report 91-220. U.S. Geological Survey. 182p.

Canada

Cherry, John A., 1987. *Groundwater Occurrence and Contamination in Canada*. Canadian Bulletin of Fisheries and Aquatic Sciences 215:387-426. Department of Fisheries and Oceans.

Environment Canada, Conservation and Protection, 1991. *A Primer On Water: Questions and Answers*. Second Edition. Minister of Supply and Services Canada, 1991. DSS Cat. No. EN 37- 90-1991E. 67p.

Environment Canada, Construction and Protection, 1990. *Clean Water — Life Depends on it!* Fact sheet. Minister of Supply and Services, Canada. Cat. No. En 37-81/3-1990E. 12p.

Environment Canada, Conservation and Protection, 1990. *Groundwater — Nature's Hidden Treasure*. Fact sheet. Minister of Supply and Services, Canada. Cat. No. En 37- 81/5 - 1990E. 12p.

Environment Canada, Conservation and Protection, 1990. *Water — Here, There and Everywhere*. Fact sheet. Minister of Supply and Services, Canada. Cat. No. En 37-81/2-1990E. 8p.

Environment Canada, Conservation and Protection, 1990. *Water — Nature's Magician*. Fact sheet. Minister of Supply and Services, Canada. Cat. No. En 37-81/1-1990E. 4p.

Environment Canada, Conservation and Protection, 1990. *Water Works!* Fact sheet. Minister of Supply and Services, Canada. Cat. No. En 37-81/4 - 1990E. 12p.

McNeely, R.N., V.P. Neimans, and L. Dwyer, 1979. *Water Quality Source Book: A Guide to Water Quality Parameters*. Environment Canada, Minister of Supply and Services Canada. Cat. No. EN 37-54-1979. 88p.

Pearse, P.H., F. Bertrand, and J.W. MacLoren, 1985. *Currents of Change: Final Report Inquiry on Federal Water Policy*. Enquiry Centre, Environment Canada, Ottawa. Cat. No. EN 37-71-1985-IE. 222p.

Royal Society of Canada and National Research Council of the United States, 1985. *The Great Lakes Water Quality Agreement: An Evolving Instrument for Ecosystem Management*. Royal Society, Ottawa, and National Research Council, Washington, D.C.

Tate, D.M., 1990. *Water Demand Management in Canada: A State-of-the-Art Review*. Inland Waters Directorate, Water Planning and Management Branch, Ottawa. Cat. No. En 36-507/23E. 52p.

B. STATE/PROVINCIAL PUBLICATIONS

Illinois

Berg, Richard C., William S. Dey, and Donald S. Keefer. Illinois Department of Energy and Natural Resources, 1990. *Potential for Aquifer Recharge in Illinois (Appropriate Recharge Areas)*.

Bowman, Jean A, 1991. *Ground-Water Quantity Laws and Management*. Report of Investigation 114, Illinois State Water Survey, Champaign. 43p.

Burch, Stephen L, 1991. *The New Chicago Model: A Reassessment of the Impacts of Lake Michigan Allocations on the Cambrian-Ordovician Aquifer System in Northeastern Illinois*. Research Report 119, Illinois State Water Survey, Champaign. 52p.

Business and Professional People for the Public Interest, 1989. *Using the New Illinois Groundwater Protection Act to Prevent Contamination of Local Water Supplies*. BPI, 17 East Monroe Street, Suite 212, Chicago, IL 60603. 11p.

Helfrich, John A., Michael J. Barcelona, Thomas R. Holm, and Susan C. Schock, 1988. *An Assessment of Regional Ground-Water Contamination in Illinois*. Illinois State Water Survey. HWRIC RR-023.

Hensel, Bruce R., Richard C. Berg, and Robert A. Griffin, 1990. *Numerical Estimates of Potential for Groundwater Contamination from Land Burial of Municipal Wastes in Illinois*. Illinois State Geological Survey. Illinois Hazardous Waste Research and Information Center. HWRIC RR-035; also State Geological Survey report EG 134.

Illinois Department of Energy and Natural Resources. *Groundwater Protection: Designing a Field Demonstration*. Video.

Illinois Department of Energy and Natural Resources. *Suggested Activities for Groundwater Protection*. Pamphlet.

Illinois Department of Energy and Natural Resources, 1991. *The Illinois Groundwater Protection Act: A Safeguard for Illinois' Water Supply*. Pamphlet.

Illinois Department of Energy and Natural Resources, 1988-92. *Illinois Groundwater Protection Gazette*.

Illinois Department of Energy and Natural Resources, 1987. *Illinois Groundwater Protection Act*. 48p.

Illinois Department of Energy and Natural Resources, Illinois State Geological Survey, Il linois State Water Survey, 1990. *An Initial Evaluation of the Impact of Pesticides on Groundwater in Illinois: Report to the Illinois Legislature.* 107p.

Illinois Department of Public Health, 1990. *Maximum Levels for Contaminants in Public Water. Nitrate in Drinking Water. Abandoned Wells.* Pamphlets.

Illinois Department of Public Health, 1989. *Requirements for Sealing Abandoned Wells.* Excerpted from Illinois Water Well Construction Code.

Illinois Environmental Protection Agency, 1988. *A Primer Regarding Certain Provisions of the Illinois Groundwater Protection Act.* 47p.

Illinois Environmental Protection Agency, Division of Public Water Supplies, 1990. *Maximum Setback Zones: Community Water Supply Groundwater Quality Protection. Groundwater Quality Protection Community Water Supply Planning.* Pamphlets.

Illinois Environmental Protection Agency, Division of Public Water Supplies, Government & Community Affairs, 1990. *Illinois Underground Storage Tank Program: A Cooperative Approach.* Pamphlet.

Illinois Groundwater Protection Act, 1992. *Mason County Groundwater Protection Field Day.* 67p.

Illinois Groundwater Protection Act, 1992. *Questions and Answers, Illinois Department of Energy and Natural Resources.* Booklet. 20p.

Illinois Hazardous Waste Research and Information Center, 1988. *Chemical Hazards in the Garage and Home Workshop. Chemical Hazards in the Home.*

Illinois State Geological Society, 1992. *Pilot Study: Agricultural Chemicals in Rural, Private Wells in Illinois.* Cooperative Illinois State Geological Society, Champaign. Groundwater report #14, 80p.

Illinois State Water Survey, 1989. *The Illinois State Water Survey.* 6p.

Interagency Coordinating Committee on Groundwater, 1992. *Illinois Groundwater Protection Program: A Biennial Report.* 118p.

Rittmann, Bruce E., Albert J. Valocchi, Joseph E. Odencrantz, and Wookeum Bae, 1988. In Situ, *Bioreclamation of Contaminated Groundwater.* Department of Civil Engineering, University of Illinois. HWRIC RR-031.

Siebel, Elisabeth Panttaja, 1982. *Groundwater Contamination in Illinois.* Illinois State Water Survey, Champaign. Brochure.

United States Department of Agriculture, Cooperative Extension Service, 1991. *Protecting Water Quality in Illinois: Nutrient and Pesticide Management Strategies.* In cooperation with the Soil Conservation Service. 52p.

University of Illinois at Urbana, College of Agriculture, Cooperative Extension Service, 1988. *Land & Water: Conserving Natural Resources in Illinois.* Series of Bulletins.

Voelker, David C., and Robert P. Clarke, 1987. *Illinois Ground-Water Quality.* U.S. Geological Survey, Books and Open-File Reports Section. 9p.

Indiana

Indiana Department of Environmental Management, 1991. *Ground Water Protection: A Guidebook.*

Indiana Department of Environmental Management, 1989. *Indiana Nonpoint Source Water Pollution Program.*

Indiana Department of Environmental Management, 1987. *The Protection of Indiana's Ground Water, Strategy and Draft Implementation Plan.*

Indiana Department of Natural Resources, 1980. *Generalized Ground Water Availability in Indiana.*

Indiana Department of Natural Resources, 1965. *Ground Water in Indiana.*

Indiana Department of Natural Resources brochures and pamphlets: *Licensing Water Well Drillers; Rules Concerning Regulation of Water Well Construction and Abandonment; Water Rights: Emergency Regulation and Standards for Protection in Ground Water Emergencies.*

Indiana Ground Water Protection Act, 1989.

Michigan

Dean, Lillian F., and Mark A. Wyckoff, 1990. *Community Planning & Zoning For Groundwater Protection in Michigan: A Guidebook for Local Officials.* Office of Water Resources, Michigan Department of Natural Resources.

Huffman, G.C., 1986. *Ground-Water Data for Michigan.* U.S. Geological Survey Open-File Report 86-417 W, in cooperation with the Michigan Department of Natural Resources. 52p.

Land and Water Management Division, 1982. *Municipal Water Withdrawals in Michigan.* Michigan Department of Natural Resources.

League of Women Voters, 1990. *Groundwater in Michigan: A Primer.* 4p.

Lusch, D., and J. Janowicz, 1990. *Agriculture's Role in Protecting Groundwater*. Groundwater Education in Michigan (GEM), Center for Remote Sensing.

Michigan Department of Management and Budget, Office of Management and Information Systems, 1986. *A Statewide Groundwater Data Base Strategy*. 209p.

Michigan Department of Natural Resources, 1989. *Executive Summary: State of Michigan Groundwater Protection Strategy and Implementation Plan*. 21p.

Michigan Department of Natural Resources, 1986. *Deep Well Injection of Hazardous Water in Michigan*. 72p.

Michigan Department of Natural Resources, Groundwater Quality Division. *Groundwater — Michigan's Hidden Resource*. 20p.

Michigan Department of Natural Resources, Office of Water Resources, 1989. *State of Michigan Groundwater Protection Strategy and Implementation Plan*. 69p.

Michigan State University, Institute of Water Research (IWR), 1987. *An Introduction to Michigan's Water Resources*. Institute of Water Research. Booklet.

Western Michigan University, 1981. *Hydrogeology for Underground Injection Control in Michigan*. U.S. Environmental Protection Agency.

Western Michigan University, Center for Water Research, Department of Geology, 1988. *Groundwater in Southwest Michigan*. 42p.

Minnesota

Minnesota Board of Water and Soil Resources, 1991. *Water Bill Board*. Newsletter published cooperatively by the Board of Water and Soil Resources, Minnesota Department of Health, Department of Natural Resources, State Planning Agency, Minnesota Department of Agriculture, and the Minnesota Pollution Control Agency. 11p.

Minnesota Department of Agriculture, 1990. *Recommendations of the Nitrogen Fertilizer Task Force on the Nitrogen Fertilizer Management Plan*. Executive Summary.

Minnesota Department of Education, 1990. *Environmental Education Act*.

Minnesota Department of Education, 1990. *Model Learner Outcomes for Environmental Education*. 10p.

Minnesota Department of Natural Resources, 1989. *Understanding Ground Water Level Trends: A Key to Managing Water Use; A Historical Summary on Ground Water Levels and Trends*. 54p.

Minnesota Environmental Quality Board, Water Resources Committee, 1991. *Minnesota Water Plan: Direction for Protecting and Conserving Minnesota's Waters*.

Minnesota State Planning Agency, 1989. *The Minnesota Ground Water Protection Act of 1989: A Summary*. 18p.

New York

New York Science, Technology and Society Education Project, 1990. *The New York Science, Technology and Society Education Project*. Brochure.

New York State, Department of Environmental Conservation, Division of Water, 1987. *FINAL Upstate New York Groundwater Management Program*. 171p.

New York State, Department of Environmental Conservation, Division of Water, 1986. *FINAL Long Island Groundwater Management Program*. 116p.

Northeast Regional Agricultural Engineering Service - Cooperative Extension, 1989. *Pesticides and Groundwater: A Guide for the Pesticide User*.

Raymond, L.S., 1988. *Groundwater Contamination*. Cornell Cooperative Extension. Booklet. 11p.

Ohio

Hanson, J.R., A.F. Woldorf, and L.P. Black, 1991. *Water Rights: An Overview of Ohio Water Withdrawal Law*. Brochure.

Harstine, Leonard J., 1991. *Hydrological Atlas for Ohio*. Ohio Department of Natural Resources, Division of Water. 13 pp., 4 plates.

Ohio Department of Natural Resources, Division of Water, 1991. *Ohio Directory of Drilling Contractors*. 61 pp.

Ohio Department of Natural Resources, Division of Water, 1991. *Ohio Water Withdrawal Registration Program, 1991 Report*. Brochure.

Ohio Department of Natural Resources, Division of Water, reprinted 1991. *Water Conservation Works*. Brochure

Ohio Department of Natural Resources, Division of Water, 1975. *What's Ground Water*. Brochure.

Ohio Environmental Protection Agency, 1992. *Ohio Wellhead Protection Program.*

Ohio Environmental Protection Agency, 1989. *Groundwater*. Booklet. 19p.

Ohio Environmental Protection Agency, 1986. *Ohio Groundwater Protection and Management Strategy.*

Ontario

Ontario Ministry of the Environment. *Water Wells in Ontario: Important Facts You Need to Know Before Having a Water Well Constructed.* Brochure.

Ontario Ministry of the Environment, 1989. *Water Wells and Ground Water Supplies in Ontario.* 98p.

Pennsylvania

Becher, A.E., 1962. *Groundwater in Pennsylvania.* Pennsylvania Geologic Survey Educational Series No. 3.

League of Women Voters of PA, 1991. *Groundwater: A Primer for Pennsylvanians.* Pennsylvania Groundwater Education Project.

Makuck, Joe, 1986. *Groundwater and Agriculture in Pennsylvania.* Pennsylvania State University, College of Agriculture, Cooperative Extension Circular 341.

Makuck, Joe, and Janice Ward, 1986. *A Quick Look at Pennsylvania Groundwater.* Pennsylvania State University and U.S. Geological Survey.

Pennsylvania Department of Education, Office of Environmental Education, 1992. Chapter 5 *Learner Outcomes for Environmental Education.*

Pennsylvania Department of Environmental Resources, 1992. *DER Groundwater Quality Protection Strategy.*

Pennsylvania Department of Environmental Resources, 1990. *Use Water Wisely.* Pamphlet.

Pennsylvania Department of Environmental Resources, 1987. *Water Conservation Program.* Pamphlet.

Pennsylvania Department of Environmental Resources, Office of Public Liaison. *Groundwater Pollution and Your Drinking Water Well.* Fact sheet.

Wisconsin

Anderson, Mary P., Kenneth R. Bradbury, and Mary W. Stoertz, 1991. *Field Investigations and Numerical Studies of Groundwater Recharge Through Unsaturated Sand: A Methodology Applied to Central Wisconsin.* Information Circular 71, University of Wisconsin - Extension, Wisconsin Geologic and Natural History Survey. 52p.

University of Wisconsin-Madison, and University of Wisconsin-Extension, College of Agricultural and Life Sciences, Cooperative Extension, 1991. *Farm*A*Syst Program - the Farmstead Assessment System.* 10 Worksheets for farmstead evaluation to protect water supplies.

Webendorfer, Bruce, and Douglas A. Yanggen, 1991. *Groundwater Protection Through Local Land-Use Controls.* Special Report 11. Wisconsin Geologic and Natural History Survey. 48p.

Wisconsin Department of Natural Resources, 1989. *Groundwater: Protecting Wisconsin's Buried Treasure.* 32p.

Wisconsin Geological and Natural History Survey, 1985. *Groundwater Protection Principles and Alternatives for Rock County, Wisconsin.* 73p.

C. OTHER PUBLICATIONS

America's Clean Water Foundation, 1990. *Public Involvement for Better Decisions: A Guidance Manual.*

Bailey, Paul E., and William D. Ward, 1990. *Understanding Ground-Water Contamination: An Orientation Manual.* ICF Incorporated.

Bisogni, Carole, Janet Fitchen, June Fessenden, Nancy Ostiguy, and Susan Turnquist, 1990. *Groundwater Contamination: Working in Partnership with Communities.* Institute for Comparative and Environmental Toxicology, Cornell University. 23p.

Bocking, Richard C., 1972. *Canada's Water: For Sale?* James Lewis and Samuel, Toronto.

Cherry, John A., Stan Feenstra, and Ronald V. Nicholson, 1988. *Groundwater in Canada: Overview of Activities and Issues and Recommendations For A National Research Strategy.* Prepared for the Science Council of Canada. 151p.

Cherry, John A., and Allan R. Freeze, 1979. *Groundwater.* Prentice-Hall Inc. College text. 604p.

Concern Inc., 1989. *Groundwater: A Community Action Guide.* 30p.

Driscoll, F. G., 1987. *Groundwater and Wells*. Second edition. Johnson Division, St. Paul, Minnesota. 1089p.

Foster, Harold D., and W.R. Derrick Sewell, 1981. *Water: The Emerging Crisis in Canada*. James Lorimer and Co. in association with the Canadian Institute for Economic Policy. Toronto.

Freshwater Foundation, 1989. *Economic Implications of Groundwater Contamination to Companies and Cities*. 80p.

Great Lakes Basin Commission, 1975. *Geology and Ground Water, Appendix 3*. Great Basin Framework Study.

Groundwater Education in Michigan (GEM), 1991. *Groundwater Reference Guide: An Annotated Bibliography of Publications Related to Groundwater Protection*. 26p.

International Joint Commission, Groundwater Contamination Task Force, 1985. *Study Proposal for Assessing Potential for Great Lakes Contamination via Groundwater*.

Keating, Michael, 1986. *To The Last Drop: Canada and the World's Water Crisis. What will we do when the clean water runs outs?* Macmillan of Canada. Toronto. 265p.

Nriagu, Jerome O., and Milijwos S. Simmons, 1984. *Toxic Contaminants in the Great Lakes*. John Wiley and Sons, Toronto.

Pennsylvania Groundwater Policy Education Project (PA-GPEP), a joint project of Penn State Cooperative Extension and the League of Women Voters of PA Citizen Education Fund (LWVPA-CEF). Vol. 2, No. 2, March/April 1992. *Groundwater Policy News*.

University of Waterloo, Department of Geography Publication Series, Occasional Paper No. 13, 1991. *Water Pipelines and Diversions in the Great Lakes Basin*. Proceedings of an International Symposium held in Waterloo, Ontario, March 12-13, 1991. 119p.

Van der Leeden, Fred L. Troise, and David Keith Todd, 1990, *The Water Encyclopedia, Second Edition*. Lewis Publications, Inc. 980p.

Waterloo Centre for Groundwater Research in cooperation with Ontario Ministry of the Environment, 1991. *Abstracts For a Conference on Groundwater Protection For Ontario*.

D. EDUCATIONAL MATERIALS

American Groundwater Trust, 1990. *Ground Water Education in America's Schools: A Catalog of Resource Materials for Elementary and Secondary Education Professionals*.

American Water Works Association, 1990. *The Story of Drinking Water*. Booklet for elementary schools.

Cedar Creek Learning Center and Tennessee Valley Authority, 1990. *Groundwater: A Vital Resource (Student Activities)*. Notebook for 3-12.

Great Lakes Commission, 1989. *Great Lakes Speakers Bureau Directory*. 69p.

Groundwater Education in Michigan Schools (GEMS), 1990. *Classroom GEMS Activities K-6*. Notebook.

International Joint Commission, 1990. *Environmental Bulletin Board: Great Lakes and Environmental Education*. An exchange of information by the participants in Teachers Making a Difference, a live-by-satellite television conference.

International Joint Commission, Science Advisory Board, 1992. *Directory of Great Lakes Educational Material*. 68p.

Iowa Department of Natural Resources, 1989. *GREAT (Groundwater Resources and Educational Activities for Teachers)*. Notebook for 7-9.

National Geographic Society, 1990. *Geography Education Program*. Educational packet.

Nebraska Groundwater Foundation, 1990. *Puddle Pictures and Dripial Pursuits*. K-12.

North Dakota State Water Commission, 1989. *WET: Water Education for Teachers*. K-12 notebook.

Pennsylvania Department of Environmental Resources, 1992. *Earth Week Classroom Program*.

Tennessee Valley Authority, Office of Natural Resources and Economic Development, Regional Water Management Program, 1988. *Catalog of Water Quality Educational Materials*. 26p.

Tennessee Valley Authority, Office of Natural Resources and Economic Development, Regional Water Management Program and Cedar Creek Learning Center, 1986. *Groundwater: A Vital Resource - Student Activities*. 61p.

U.S. Environmental Protection Agency, Great Lakes National Program Office, 1990. *Great Minds? Great Lakes!* K-8 lesson plans.

University of Illinois and Purdue University, Cooperative Extension Service, 4-H Youth

Programs, 1983. *Wetlands are Wonderlands Teacher/Leader and Youth/Member Guides of the 4-H Marine Education Series - 1.* 27p.

Virginia Water Resources Research Center, 1987. *Sandcastle Moats and Petunia Bed Holes: A Book About Groundwater.* Booklet.

Water Pollution Control Federation, 1990. *The Groundwater Adventure.* K-12 curriculum book.

Williams, D.L. and E.C. Weber, 1990. *Groundwater Protection Through Prevention. A Curriculum for Agricultural Education in Secondary Schools.*

Wilson, C., et al., 1989. *Outlook on Groundwater.* K-12 curriculum. Institute for Environmental Education, Cedar Falls, IA.

Classroom-Ready Materials

Alexander, Dane, Terr Hass, Richard N. Passero, and Rudy Ziehl, 1991. *Ground-Water Transparencies: Instructional Resources for Michigan Educators.* GEM Regional Center, Institute for Water Resources, Western Michigan University.

Bailey, Ann, 1993. *Excuse me sir, that's my Aquifer!* Au Sable Institute of Environmental Studies. Audio cassette and booklet. 20p.

Federation of Ontario Naturalists, 1989. *Great Lakes Teachers Guide.* 75p.

Groundwater Education in Michigan Schools (GEMS), SEE-North, 1990. *Classroom GEMS.* K-12 classroom activities.

Illinois Department of Energy and Natural Resources, 1989. *Illinois Groundwater: Our Invisible Resource - Teacher's Guide.* 7p.

Kraut, Ruth, 1990. *GEE-WOW! Adventures in Water Education.* K-3 curriculum. Ecology Center, Ann Arbor, MI.

Lake Michigan Federation and Great Lakes Commission, 1991. *The Great Lakes in My World: An Activities Workbook for Grades K-8.* 160p.

Pennsylvania Department of Environmental Resources, Water Conservation/Technical Assistance Program, 1991. *Instructor's Guide to Water Education Activities.* K-12 Curriculum. 56p.

Project Wild, 1987. *Aquatic.* K-12 curriculum. Western Regional Environmental Education Council.

Soil and Water Conservation Society, 1990. *Water in Your Hands.* Educational comic book with Teacher's Guide.

U.S. Department of Agriculture, Soil Conservation Service, 1986. *Teaching Soil and Water Conservation: A Classroom and Field Guide.* 29p.

U.S. Environmental Protection Agency, Office of Water & Waste Management, 1980. *Let's Recycle!: Lessons Plans for Grades K- 6 and 7-12.* 42p.

Wisconsin Department of Natural Resources, Bureau of Information and Education, Education Section, 1990. *Groundwater Study Guide.* 35p.

Appendix A

REGIONAL INITIATIVES

REGIONAL PROGRAMS — U.S.-CANADIAN

There is not a single program focused on groundwater protection in the Great Lakes Basin. There are, however, models of binational cooperation for the joint management and protection of the Great Lakes water resources. Since the 1909 International Boundary Waters Treaty established the U.S. – Canadian International Joint Commission (IJC), this binational body of federally appointed representatives has sought common solutions to the shared problems of both countries. The IJC's primary responsibility, as conducted through its Water Quality and Science Advisory Boards, is to study specific problems as requested by the U.S. and Canadian governments and to make recommendations for joint actions to promote the conservation and beneficial use of the Great Lakes water resources. The IJC also has limited authority for approving water diversions and withdrawals from the boundary waters as well as for binational dispute resolution.

Important milestones in this binational management effort include:

The 1972 Great Lakes Water Quality Agreement (GLWQA) established common water quality objectives and set forth a process by which both nations would 1) control pollution, 2) establish Great Lakes research programs, and 3) perform surveillance and monitoring to identify problems and measure progress in solving those problems. Discoveries under this program, such as the significant water quality impacts of long-range atmospheric transport of toxic contaminants to remote parts of Lake Superior, reconfirmed the need for joint management as well as its necessity in dealing effectively with the region as a single hydrologic unit.

The 1978 amendments to the Great Lakes Water Quality Agreement reaffirmed the principles of the 1972 agreement but went further by calling for what has come to be known as an "ecosystem approach" to Great Lakes management. This is significant because it takes into account the interactions of all the components of the Basin's ecosystem — including humans — and thus seeks much more strict pollution controls that consider ecological phenomenon, such as biomagnification, as well as diffuse sources of water pollution, such as runoff from urban land uses and contaminated groundwater discharge.

In 1987 a host of amendments, including one that deals specifically with groundwater contamination, were added to the GLWQA. This groundwater amendment calls for coordinated efforts for groundwater protection and research needs at the Basin level. At present, Canada and the U.S. have undertaken almost no cooperative action for groundwater protection.

Great Lakes Charter. In 1985, the region's governors and premiers signed the Great Lakes Charter, a series of principles for the management of Great Lakes water resources. The Charter, developed by the Great Lakes Governors' Task Force on Water Diversions and Great Lakes Institutions, is a "good-faith" agreement between the region's states and provinces outlining the goals for the cooperative management of Great Lakes waters. It represents an important step toward regional unity that was developed in response to the threat of water diversions from the Great Lakes to other regions of the U.S. facing water shortages. The Charter commits the states and provinces to exchange information, develop their own water management programs, and consult with other jurisdictions prior to taking actions that may affect the Lakes.

The Great Lakes Toxic Substances Control Agreement signed in 1986 by all the Great Lakes governors and in 1988 by the premiers of Quebec and Ontario, is another example of the regional management approach pioneered by the Charter. The Agreement responds to the finding of toxic pollution as the "foremost environmental issue confronting the Great Lakes." It sets forth a regional action strategy by which the states and provinces aim to minimize toxic contamination by cooperating in programs to study, manage, and monitor the Lakes.

Appendix B

GLOSSARY OF GROUNDWATER TERMS

Aquifer: A layer of soil or rock filled with water and capable of supplying water to wells.

Aquitard: A layer of soil or rock with very low permeability which acts to slow the movement of groundwater; usually very fine-grained material such as clay or silt.

Artesian well: A well which taps a confined aquifer. If the water pressure is high enough in the aquifer, the water will be forced to flow up and out of the well, as in a flowing artesian well.

Basement rocks: Ancient bedrock which underlies the entire Great Lakes Basin, consisting of igneous and metamorphic rocks.

Bedrock: A solid and continuous layer of rock which underlies surface deposits and soils.

Confined (artesian) **aquifer:** An aquifer which is held under pressure by an impermeable overlying layer.

Evaporation: The process by which water changes into a gas.

Evapotranspiration: The evaporation of water from vegetation.

Geology: The study of the earth's history, structure, and materials, as well as the processes occurring within the earth and on its surface.

Glacial drift: The sediments transported and deposited by glaciers or by water melting from the glaciers.

Groundwater: Water that fills up the pore spaces in soil and rock.

Groundwater table: See Water table.

Hardness: A measure of calcium and magnesium salts dissolved in water. Hard water doesn't dissolve soaps as well, leaves scales in pipes and heaters, and stains sinks.

Hydrogeology: The study of groundwater.

Hydrologic cycle: The cycle of water's movement from the atmosphere through the landscape and back to the atmosphere.

Hydrology: The study of the processes by which water moves through the hydrologic cycle.

Induced recharge: The artificial infiltration of water from a stream to an adjacent aquifer. The infiltration is created by pumping in a well and is an important technique for water supply management.

Impermeable: Not allowing water to pass through it. Because beds of clays and other fine sediments are nearly impermeable, they act as confining layers and impede the spread of contaminated groundwater.

Infiltration: The downward movement of water into and through the soil.

Leachate: Water which has become contaminated by the waste materials it moves through. Leachate from a landfill is contaminated with organic substances and dissolved chemicals.

Limestone: A water soluble rock consisting mainly of the mineral calcite (calcium carbonate).

Mineral: A naturally occurring compound that has a crystalline structure and a unique elemental composition.

Nonpoint source pollution: A major contaminant source category; pollution originating from dispersed sources such as agricultural activities, urban runoff, and atmospheric deposition. (See point source pollution.)

Organic Chemicals: A large class of chemical compounds that contain carbon. Synthetic organic chemicals are those created in a laboratory. These are the most common industrial and household chemicals and are common contaminants in groundwater.

Permeable: Open to penetration of water.

Point source pollution: A major contaminant source category; pollution originating from a discrete source such as an industrial discharge pipe or a leaking underground storage tank. (See nonpoint source pollution.)

Potable: Safe for drinking.

Public/municipal water supply: Water withdrawn for all uses by public and private water suppliers and delivered to users that do not supply their own water.

Recharge: The resupply of water to an aquifer. Natural recharge is supplied by precipitation infiltrating through the soil and into an aquifer.

Runoff: Water moving over the surface of the land. Runoff originates as precipitation which does not infiltrate into the ground but begins to flow over land. Excessive runoff causes flooding and erosion.

Saturated zone: The area of soil or rock in which all open spaces are filled with water.

Self supply: Any water supply that users provide for themselves through wells or surface water withdrawals.

Septic tank: A holding and settling tank used for sewage treatment. The tank separates out solids which are decomposed by bacteria and allows wastewater to disperse into the soil via a drainage field.

Sludge: The solid remains of the sewage treatment process.

Spring: The point where the water table intersects the ground surface, discharging water.

Topography: The shape and elevation of the land surface.

Toxin: A substance which is hazardous or poisonous for humans, animals, or vegetation.

Unconfined aquifer: An aquifer containing water at the same pressure as the atmosphere. Because it is not overlain by an impermeable layer, the aquifer's water level (water table) fluctuates according to seasonal variations in recharge.

Vadose zone: A region of rock or soil which is moist or wet and lies directly above the water table.

VOC: Volatile organic compound. Any hydrocarbon compound, pollutant or chemical, which evaporates rapidly in air at moderate ambient temperatures.

Water table: The topmost level of the saturated zone or the level below which the soil and rock is completely saturated (filled with water). Synonymous with groundwater table.

Well: A hole which penetrates a groundwater aquifer. Usually built with a vertical pipe called a well casing that is perforated (screened) to allow water to enter.

Wetland: An area, such as a bog, swamp, or marsh, which has seasonally wet soils and a distinct plant community. Wetlands are usually found in close proximity to the groundwater table.

Appendix C

Unit of Measure Conversion Table

U.S. and Metric Units listed alphabetically

When You Know	Multiply By	To Convert To
LENGTH Units:		
centimeters (cm)	0.394	inches
centimeters (cm)	0.0328	feet
feet (ft)	30.48	centimeters
feet (ft)	0.305	meters
inches (in)	2.54	centimeters
kilometers (km)	0.621	miles
meters (m)	3.28	feet
meters (m)	1.094	yards
miles (mi)	1.61	kilometers
yards (yd)	0.914	meters
AREA Units:		
acres	0.405	hectares
hectares (ha)	2.47	acres
square kilometers (km^2)	0.386	square miles
square miles (mi^2)	2.59	square kilometers
WEIGHT Units:		
grams (g)	0.0353	ounces
kilograms (kg)	2.20	pounds
ounces (oz)	28.3	grams
pounds (lb)	0.454	kilograms
VOLUME Units:		
cubic feet (ft^3)	0.0283	cubic meters
cubic meters (m^3)	35.3	cubic feet
cubic yards (yd^3)	0.765	cubic meters
gallons (gal)	3.785	liters
liters (L)	0.264	gallons
FLOW RATE Units:		
cubic feet per second (cfs)	0.0283	cubic meters per second
cubic meters per second (cms)	35.3	cubic feet per second
gallons per minute (gpm)	3.785	liters per minute
liters per minute (L/m)	0.264	gallons per minute
liters per second (L/s)	15.85	gallons per minute
CONCENTRATION Units:		
milligrams per liter (mg/L)	1.00	parts per million
micrograms per liter (ug/L)	1.00	parts per billion
parts per million (ppm)	1.00	milligrams per liter
parts per billion (ppb)	1.00	micrograms per liter

Appendix D

Great Lakes Groundwater Education Task Force

ILLINOIS
Gary Clark
Chief of Planning & Research
Bureau of Program Development
IDOT/Division of Water Resources
2300 S. Dirksen Parkway, Room 339
Springfield, IL 62764
217-782-3488

Harry Hendrickson
Groundwater Education Coordinator
Research and Planning
IL Dept. of Energy & Natural Resources
325 W. Adams, Floor 1
Springfield, IL 62704
217-785-8577

INDIANA
Judith Beaty
Basin Studies Section
Indiana DNR, Division of Water
402 W. Washington, Room W264
Indianapolis, IN 46204
317-232-4222

James Hebenstreit, Assist Director
Indiana DNR, Division of Water
402 W. Washington, Room W264
Indianapolis, IN 46204
317-232-4163

MICHIGAN
Steve Miller
Office of Water Resources
Michigan Dept. Natural Resources
P.O. Box 30028
Lansing, MI 48909
517-373-0014

Mozell Lange
Science Specialist
Michigan Dept. of Education
608 W. Allegan
Ottawa South Bldg. -2nd Fl.
School Program Services
Lansing, MI 48909
517-373-4223

MINNESOTA
John Wells, Director
Environmental Quality Board
Water Resources Committee
Minnesota State Planning Agency
Environmental Division
658 Cedar St., 300 Centennial Bldg.
St. Paul, MN 55155
612-297-2377

NEW YORK
Salvatore Pagano, Director
Division of Water
New York Department of Environmental Conservation
50 Wolf Rd.
Albany, NY 12233
518-457-6674

OHIO
Tom Allen
Division of Groundwater
Ohio Environmental Protection Agency
1800 Watermark Dr.
P.O. Box 1049
Columbus, OH 43226-0149
614-644-2905

Rebecca Petty
Division of Water
Ohio Dept. of Natural Resources
1939 Fountain Square, Bldg. E-1
Columbus, OH 43224
614-265-6744

PENNSYLVANIA
Paul Zeph
Community Relations Liaison
Office of Public Liaison
PA Dept. of Environmental Resources
P.O. Box 2063
Harrisburg, PA 17105-2063
717-783-7005

WISCONSIN
Gary Jackson
Extension Service
National Farm Assistance Prog. Coord.
B 142 Steenboch Library
University of WI
Madison, WI 53706
608-265-2773

Cathy Cliff
Bureau of Information & Education
WI Dept. of Natural Resources
P.O. Box 7921
Madison, WI 53707-7921
608-267-7529

FEDERAL
Joseph R. Wanielista
Plan Formulation Branch Planning Div.
U.S. Army Corps of Engineers
Detroit District
P.O. Box 1027
Detroit, MI 48231
313-226-6773

Ruth D. Shaffer
Water Quality Specialist
USDA - Soil Conservation Service
1405 S. Harrison Rd.
Lansing, MI 48823
517-337-6718

Kelly Warner
U.S.G.S.
Water Resources Division
102 E. Main St., 4th Floor
Urbana, IL 61801
217-398-5368

Barbara West
National Park Service
Water Resource Division
P.O. Box 25287
Denver, CO 80225
303-969-2815

REGIONAL

Mike Libbee
Michigan Geographic Alliance
c/o Department of Geography
Central Michigan University
Mount Pleasant, MI 48859
517-774-3723

Jessica Kovan
W.K. Kellogg Foundation
One Michigan Avenue East
Battle Creek, MI 49017
616-968-1611

Linda Helstowski, Director
GEM Program
Institute of Water Research
Michigan State University
334 Natural Resources Bldg.
East Lansing, MI 48824-1222
517-353-3742

Carol Misseldine, Executive Director
Michigan Environmental Council
115 W. Allegan, Suite 10B
Lansing, MI 48933
517-487-9539

GREAT LAKES COMMISSION STAFF

Tom Crane, Program Manager
Resource Management and Environmental Quality

Carol Ratza, Program Manager
Communications

Martha Reesman, Program Manager
Special Projects (through June 1992)

Paul Feder
Research Associate (through May 1992)

Rita Straith
Administrative Assistant

Paula McIntyre
Communications Specialist

The Argus II Building
400 Fourth St.
Ann Arbor, MI 48103-4816
313-665-9135

GROUNDWATER CONTACTS AND NOTES

GROUNDWATER CONTACTS AND NOTES

Printed on recycled paper

Great Lakes Commission
The Argus II Building
400 Fourth Street
Ann Arbor, MI 48103-4816
(313) 665-9135

The Great Lakes Commission is an eight state compact agency that guides, protects and advances the common interests of its membership in areas of regional environmental quality, resource management and economic development.

Established in 1955 by the Great Lakes Basin Compact and founded in state and federal law, the Commission is comprised of state officials, legislators and Governors' appointees. Its research, policy and advocacy activities are unique to the region and dedicated to securing a strong economy, clean environment and high quality of life for the Great Lakes region and its citizenry.