GROUND WATER POLLUTION POTENTIAL OF GEAUGA COUNTY, OHIO

BY

LINDA ALLER AND KAREN L. BALLOU

GEODESY, INC.

GROUND WATER POLLUTION POTENTIAL REPORT NO. 12

OHIO DEPARTMENT OF NATURAL RESOURCES

DIVISION OF WATER

GROUND WATER RESOURCES SECTION

JUNE, 1994

ABSTRACT

A ground water pollution potential mapping program for Ohio has been developed under the direction of the Division of Water, Ohio Department of Natural Resources, using the DRASTIC mapping process. The DRASTIC system consists of two major elements: the designation of mappable units, termed hydrogeologic settings, and the superposition of a relative rating system for pollution potential.

Hydrogeologic settings form the basis of the system and incorporate the major hydrogeologic factors that affect and control ground water movement and occurrence including depth to water, net recharge, aquifer media, soil media, topography, impact of the vadose zone media, and hydraulic conductivity of the aquifer. These factors, which form the acronym DRASTIC, are incorporated into a relative ranking scheme that uses a combination of weights and ratings to produce a numerical value called the ground water pollution potential index. Hydrogeologic settings are combined with the pollution potential indexes to create units that can be graphically displayed on a map.

Geauga County lies within the Southern New York Section of the Appalachian Plateau Province (Fenneman, 1938). The entire county is covered by a variable thickness of glacial till and outwash sand and gravel. These unconsolidated glacial deposits overlie Devonian, Mississippian and Pennsylvanian sandstones, conglomerates, and shales. Ground water yields are dependant on the type of aquifer and vary greatly throughout the county. Pollution potential indexes are relatively low to moderate in areas of till or lacustrine cover over bedrock, and moderate to moderately high in areas with alluvial cover. Buried valleys containing sand and gravel aquifers, and areas covered by outwash, have low to high vulnerabilities to contamination.

Ground water pollution potential analysis in Geauga County resulted in a map with symbols and colors which illustrate areas of varying ground water contamination vulnerability. Eight hydrogeologic settings were identified in Geauga County with computed ground water pollution potential indexes ranging from 80 to 207.

The ground water pollution potential mapping program optimizes the use of existing data to rank areas with respect to relative vulnerability to contamination. The ground water pollution potential map of Geauga County has been prepared to assist planners, managers, and local officials in evaluating the potential for contamination from various sources of pollution. This information can be used to help direct resources and land use activities to appropriate areas, or to assist in protection, monitoring, and clean-up efforts

ACKNOWLEDGEMENTS

The preparation of the Geauga County Ground Water Pollution Potential report and map involved the contribution and work of a number of individuals in the Division of Water. Grateful acknowledgement is given to the following individuals for their technical review and map production, text authorship, report editing and preparation:

Map preparation and review:	Michael Hallfrisch Michael Angle Rebecca Petty
Map print production and review:	David Orr Michael Hallfrisch
Report production and review:	Rebecca Petty Michael Hallfrisch Michael Angle Linda Fair
Report editing:	Rebecca Petty Michael Hallfrisch J. Mc Call-Neubauer
Desktop publishing and report design	David Orr Denise L. Spencer

TABLE OF CONTENTS

Page

LIST OF FIGURES

Number Page

LIST OF TABLES

Number | Page

INTRODUCTION

The need for protection and management of ground water resources in Ohio has been clearly recognized. About 42 per cent of Ohio citizens rely on ground water for their drinking and household uses from both municipal and private wells. Industry and agriculture also utilize significant quantities of ground water for processing and irrigation. In Ohio, approximately 700,000 rural households depend on private wells; approximately 24,800 of these wells exist in Geauga County.

The characteristics of the many aquifer systems in the state make ground water highly vulnerable to contamination. Measures to protect ground water from contamination usually cost less and create less impact on ground water users than clean-up of a polluted aquifer. Based on these concerns for protection of the resource, staff of the Division of Water conducted a review of various mapping strategies useful for identifying vulnerable aquifer areas. They placed particular emphasis on reviewing mapping systems that would assist in state and local protection and management programs. Based on these factors and the quantity and quality of available data on ground water resources, the DRASTIC mapping process (Aller et al., 1987) was selected for application in the program.

Considerable interest in the mapping program followed successful production of a demonstration county map and led to the inclusion of the program as a recommended initiative in the Ohio Ground Water Protection and Management Strategy (Ohio EPA, 1986). Based on this recommendation, the Ohio General Assembly funded the mapping program. A dedicated mapping unit has been established in the Division of Water, Ground Water Resources Section to implement the ground water pollution potential mapping program on a county-wide basis in Ohio.

The purpose of this report and map is to aid in the protection of our ground water resources. This protection can be enhanced by understanding and implementing the results of this study which utilizes the DRASTIC system of evaluating an area's potential for ground-water pollution. The mapping program identifies areas that are more or less vulnerable to contamination and displays this information graphically on maps. The system was not designed or intended to replace site-specific investigations, but rather to be used as a planning and management tool. The results of the map and report can be combined with other information to assist in prioritizing local resources and in making land use decisions.

APPLICATIONS OF POLLUTION POTENTIAL MAPS

The pollution potential mapping program offers a wide variety of applications in many counties. The ground water pollution potential map of Geauga County has been prepared to assist planners, managers, and state and local officials in evaluating the relative vulnerability of areas to ground water contamination from various sources of pollution. This information can be used to help direct resources and land use activities to appropriate areas, or to assist in protection, monitoring and clean-up efforts.

An important application of the pollution potential maps for many areas will be to assist in county land use planning and resource expenditure allocation related to solid waste disposal. A county may use the map to help identify areas that are more or less suitable for land disposal activities. Once these areas have been identified, a county can collect more site-specific information and combine this with other local factors to determine site suitability.

A pollution potential map can also assist in developing ground water protection strategies. By identifying areas more vulnerable to contamination, officials can direct resources to areas where special attention or protection efforts might be warranted. This information can be utilized effectively at the local level for integration into land use decisions and as an educational tool to promote public awareness of ground water resources. Pollution potential maps may also be used to prioritize ground water monitoring and/or contamination clean-up efforts. Areas that are identified as being vulnerable to contamination may benefit from increased ground water monitoring for pollutants or from additional efforts to clean up an aquifer.

Other beneficial uses of the pollution potential maps will be recognized by individuals in the county who are familiar with specific land use and management problems. Planning commissions and zoning boards can use these maps to help make informed decisions about the development of areas within their jurisdiction. Developments proposed to occur within ground-water sensitive areas may be required to show how ground water will be protected.

Regardless of the application, emphasis must be placed on the fact that the system is not designed to replace a site-specific investigation. The strength of the system lies in its ability to make a "first-cut approximation" by identifying areas that are vulnerable to contamination. Any potential applications of the system should also recognize the assumptions inherent in the system.

SUMMARY OF THE DRASTIC MAPPING PROCESS

The system chosen for implementation of a ground water pollution potential mapping program in Ohio, DRASTIC, was developed by the National Water Well Association for the United States Environmental Protection Agency. A detailed discussion of this system can be found in Aller et al. (1987).

The DRASTIC mapping system allows the pollution potential of any area to be evaluated systematically using existing information. The vulnerability of an area to contamination is a combination of hydrogeologic factors, anthropogenic influences, and sources of contamination in any given area. The DRASTIC system focuses only on those hydrogeologic factors which influence ground water pollution potential. The system consists of two major elements: the designation of mappable units, termed hydrogeologic settings, and the superposition of a relative rating system to determine pollution potential.

The application of DRASTIC to an area requires the recognition of a set of assumptions made in the development of the system. DRASTIC evaluates the pollution potential of an area assuming a contaminant with the mobility of water, introduced at the surface, and flushed into the ground water by precipitation. Most important, DRASTIC cannot be applied to areas smaller than one-hundred acres in size, and is not intended or designed to replace site-specific investigations.

Hydrogeologic Settings and Factors

To facilitate the designation of mappable units, the DRASTIC system used the framework of an existing classification system developed by Heath (1984), which divides the United States into fifteen ground water regions based on the factors in a ground water system that affect occurrence and availability.

Within each major hydrogeologic region, smaller units representing specific hydrogeologic settings are identified. Hydrogeologic settings form the basis of the system and represent a composite description of the major geologic and hydrogeologic factors that control ground water movement into, through and out of an area. A hydrogeologic setting represents a mappable unit with common hydrogeologic characteristics, and, as a consequence, common vulnerability to contamination (Aller et al., 1987).

Figure 1 illustrates the format and description of a typical hydrogeologic setting found within Geauga County. Inherent within each hydrogeologic setting are the physical characteristics which affect the ground water pollution potential. These characteristics or factors identified during the development of the DRASTIC system include:

D - Depth to Water

R - Net Recharge

A - Aquifer Media

S - Soil Media

T - Topography

I - Impact of the Vadose Zone Media

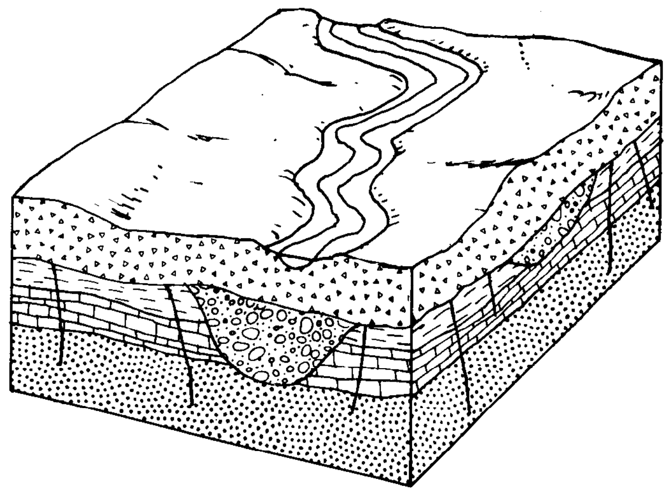
C - Conductivity (Hydraulic) of the Aquifer

These factors incorporate concepts and mechanisms such as attenuation, retardation and time or distance of travel of a contaminant with respect to the physical characteristics of the hydrogeologic setting. Broad consideration of these factors and mechanisms coupled with existing conditions in a setting provide a basis for determination of the area's relative vulnerability to contamination.

Depth to water is considered to be the depth from the ground surface to the water table in unconfined aquifer conditions or the depth to the top of the aquifer under confined aquifer conditions. The depth to water determines the distance a contaminant would have to travel before reaching the aquifer. The greater the distance the contaminant has to travel the greater the opportunity for attenuation to occur or restriction of movement by relatively impermeable layers.

Net recharge is the total amount of water reaching the land surface that infiltrates into the aquifer measured in inches per year. Recharge water is available to transport a contaminant from the surface into the aquifer and also affects the quantity of water available for dilution and dispersion of a contaminant. Factors to be included in the determination of net recharge include contributions due to infiltration of precipitation, in addition to infiltration from rivers, streams and lakes, irrigation, and artificial recharge.

Aquifer media represents consolidated or unconsolidated rock material capable of yielding sufficient quantities of water for use. Aquifer media accounts for the various physical characteristics of the rock that provide mechanisms of attenuation, retardation, and flow pathways that affect a contaminant reaching and moving through an aquifer.



7D Buried Valleys

This hydrogeologic setting is characterized by thick deposits of sand and gravel that have been deposited in a former topographic low (usually a pre-glacial river valley) by glacial meltwaters. These deposits are capable of yielding large quantities of ground water. The deposits may or may not underlie a present-day river and may or may not be in direct hydraulic connection with a stream. Glacial till or recent alluvium often overlies the buried valley. Usually the deposits are several times more permeable than the surrounding bedrock. Soils are typically a sandy loam. Recharge to the sand and gravel is moderate and water levels are commonly relatively shallow, although they may be quite variable.

Figure 1. Format and description of the hydrogeologic setting - 7D Buried Valleys.

Soil media refers to the upper six feet of the unsaturated zone that is characterized by significant biological activity. The type of soil media can influence the amount of recharge that can move through the soil column due to variations in soil permeability. Various soil types also have the ability to attenuate or retard a contaminant as it moves throughout the soil profile. Soil media is based on textural classifications of soils and considers relative thicknesses and attenuation characteristics of each profile within the soil.

Topography refers to the slope of the land expressed as percent slope. The amount of slope in an area affects the likelihood that a contaminant will run off from an area or be ponded and ultimately infiltrate into the subsurface. Topography also affects soil development and often can be used to help determine the direction and gradient of ground water flow under water table conditions.

The impact of the vadose zone media refers to the attenuation and retardation processes that can occur as a contaminant moves through the unsaturated zone above the aquifer. The vadose zone represents that area below the soil horizon and above the aquifer that is unsaturated or discontinuously saturated. Various attenuation, travel time, and distance mechanisms related to the types of geologic materials present can affect the movement of contaminants in the vadose zone. Where an aquifer is unconfined, the vadose zone media represents the materials below the soil horizon and above the water table. Under confined aquifer conditions, the vadose zone is simply referred to as a confining layer. The presence of the confining layer in the unsaturated zone significantly impacts the pollution potential of the ground water in an area

Hydraulic conductivity of an aquifer is a measure of the ability of the aquifer to transmit water, and is also related to ground water velocity and gradient. Hydraulic conductivity is dependent upon the amount and interconnectivity of void spaces and fractures within a consolidated or unconsolidated rock unit. Higher hydraulic conductivity typically corresponds to higher vulnerability to contamination. Hydraulic conductivity considers the capability for a contaminant that reaches an aquifer to be transported throughout that aquifer over time.

Weighting and Rating System

DRASTIC uses a numerical weighting and rating system that is combined with the DRASTIC factors to calculate a ground water pollution potential index or relative measure of vulnerability to contamination. The DRASTIC factors are weighted from 1 to 5 according to their relative importance to each other with regard to contamination potential (Table 1). Each factor is then divided into ranges or media types and assigned a rating from 1 to 10 based on their significance to pollution potential (Tables 2-8). The rating for each factor is selected based on available information and professional judgement. The selected rating for each factor is multiplied by the assigned weight for each factor. These numbers are summed to calculate the DRASTIC or pollution potential index.

Once a DRASTIC index has been calculated, it is possible to identify areas that are more likely to be susceptible to ground water contamination relative to other areas. The higher the DRASTIC index, the greater the vulnerability to contamination. The index generated provides only a relative evaluation tool and is not designed to produce absolute answers or to represent units of vulnerability. Pollution potential indexes of various settings should be compared to each other only with consideration of the factors that were evaluated in determining the vulnerability of the area.

Pesticide DRASTIC

A special version of DRASTIC was developed to be used where the application of pesticides is a concern. The weights assigned to the DRASTIC factors were changed to reflect the processes that affect pesticide movement into the subsurface with particular emphasis on soils. The process for calculating the Pesticide DRASTIC index is identical to the process used for calculating the general DRASTIC index. However, general DRASTIC and Pesticide DRASTIC numbers should not be compared because the conceptual basis in factor weighting and evaluation significantly differs.

TABLE 1. ASSIGNED WEIGHTS FOR DRASTIC FEATURES

Feature	General DRASTIC Weight	Pesticide DRASTIC Weight
Depth to Water	5	5
Net Recharge	4	4
Aquifer Media	3	3
Soil Media	2	5
Topography	1	3
Impact of the Vadose Zone Media	5	4
Hydraulic Conductivity of the Aquifer	3	2

TABLE 2. RANGES AND RATINGS FOR DEPTH TO WATER

DEPTH TO WATER (FEET)	
Range	Rating
0-5	10
5-15	9
15-30	7
30-50	5
50-75	3
75-100	2
100+	1
Weight: 5	Pesticide Weight: 5

TABLE 3. RANGES AND RATINGS FOR NET RECHARGE

NET RECHARGE (INCHES)	
Range	Rating
0-2	1
2-4	3
4-7	6
7-10	8
10+	9
Weight: 4	Pesticide Weight: 4

TABLE 4. RANGES AND RATINGS FOR AQUIFER MEDIA

AQUIFER MEDIA		
Range	Rating	Typical Rating
Massive Shale	1-3	2
Metamorphic/Igneous	2-5	3
Weathered Metamorphic / Igneous	3-5	4
Glacial Till	4-6	5
Bedded Sandstone, Limestone and Shale Sequences	5-9	6
Massive Sandstone	4-9	6
Massive Limestone	4-9	6
Sand and Gravel	4-9	8
Basalt	2-10	9
Karst Limestone	9-10	10
Weight: 3	Pesticide Weight: 3	

TABLE 5. RANGES AND RATINGS FOR SOIL MEDIA

SOIL MEDIA	
Range	Rating
Thin or Absent	10
Gravel	10
Sand	9
Peat	8
Shrinking and / or Aggregated Clay	7
Sandy Loam	6
Loam	5
Silty Loam	4
Clay Loam	3
Muck	2
Nonshrinking and Nonaggregated Clay	1
Weight: 2	Pesticide Weight: 5

TABLE 6. RANGES AND RATINGS FOR TOPOGRAPHY

TOPOGRAPHY (PERCENT SLOPE)	
Range	Rating
0-2	10
2-6	9
6-12	5
12-18	3
18+	1
Weight: 1	Pesticide Weight: 3

TABLE 7. RANGES AND RATINGS FOR IMPACT OF THE VADOSE ZONE MEDIA

IMPACT OF THE VADOSE ZONE MEDIA		
Range	Rating	Typical Rating
Confining Layer	1	1
Silt/Clay	2-6	3
Shale	2-5	3
LImestone	2-7	6
Sandstone	4-8	6
Bedded Limestone, Sandstone, Shale	4-8	6
Sand and Gravel with significant Silt and Clay	4-8	6
Metamorphic/Igneous	2-8	4
Sand and Gravel	6-9	8
Basalt	2-10	9
Karst Limestone	8-10	10
Weight: 5	Pesticide Weight: 4	

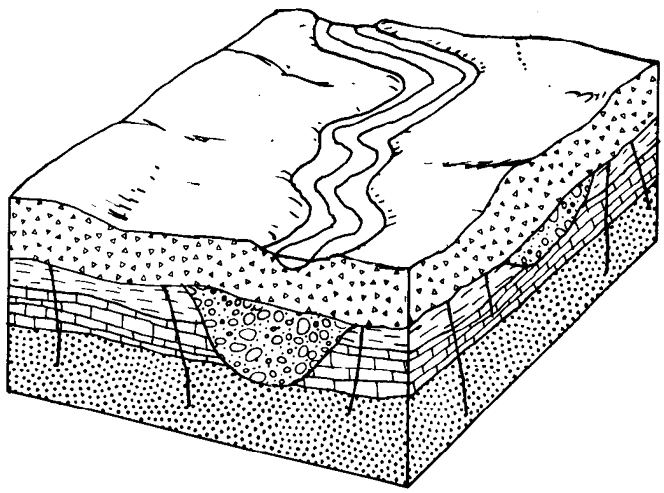
TABLE 8. RANGES AND RATINGS FOR HYDRAULIC CONDUCTIVITY

HYDRAULIC CONDUCTIVITY (GPD/FT^2)	
Range	Rating
1-100	1
100-300	2
300-700	4
700-1000	6
1000-2000	8
2000+	10
Weight: 3	Pesticide Weight: 2

Integration of Hydrogeologic Settings and DRASTIC Factors

Figure 2 illustrates the hydrogeologic setting 7D1 Buried Valley, identified in mapping Geauga County, and the pollution potential index calculated for the setting. Based on selected ratings for this setting, the pollution potential index is calculated to be 87. This numerical value has no intrinsic meaning, but can be readily compared to a value obtained for other settings in the county. DRASTIC indexes for typical hydrogeologic settings and values across the United States range from 45 to 223. The diversity of hydrogeologic conditions in Geauga County produces settings with a wide range of vulnerability to ground water contamination. Calculated pollution potential indexes for the eight settings identified in the county range from 80 to 207.

Hydrogeologic settings identified in an area are combined with the pollution potential indexes to create units that can be graphically displayed on maps. Pollution potential analysis in Geauga County resulted in a map with symbols and colors that illustrate areas of ground water vulnerability. The map describing the ground water pollution potential of Geauga County is included with this report.



SETTING 7D1		GENERAL		
FEATURE	RANGE	WEIGHT	RATING	NUMBER
Depth to Water	30-50	5	5	25
Net Recharge	2 - 4	4	3	12
Aquifer Media	Sand & Gravel	3	5	15
Soil Media	Silty Loam	2	4	8
Topography	18+	1	1	1
Impact Vadose Zone	Silt/Clay	5	4	20
Hydraulic Conductivity	100-300	3	2	6
		DRASTIC	INDEX	87

Figure 2. Description of the hydrogeologic setting - 7D1 Buried Valley.

INTERPRETATION AND USE OF A GROUND WATER POLLUTION POTENTIAL MAP

The application of the DRASTIC system to evaluate an area's vulnerability to contamination produces hydrogeologic settings with corresponding pollution potential indexes. The higher the pollution potential index, the greater the susceptibility to contamination. This numeric value determined for one area can be compared to the pollution potential index calculated for another area.

The map accompanying this report displays both the hydrogeologic settings identified in the county and the associated pollution potential indexes calculated in those hydrogeologic settings. The symbols on the map represent the following information:

7D1 - defines the hydrogeologic region and setting
87 - defines the relative pollution potential

Here the first number (7D1) refers to the major hydrogeologic region and the upper case refers to a specific hydrogeologic setting. The following number references a certain set of DRASTIC parameters that are unique to this setting and are described in the corresponding setting chart. The second number (87) is the calculated pollution potential index for this unique setting. The charts for each setting provide a reference to show how the pollution potential index was derived in an area.

The maps are color coded using ranges depicted on the map legend. The color codes used are part of a national color coding scheme developed to assist the user in gaining a general insight into the vulnerability of the ground water in the area. The color codes were chosen to represent the colors of the spectrum, with warm colors (red, orange, and yellow), representing areas of higher vulnerability (higher pollution potential indexes), and cool colors (greens, blues, and violet), representing areas of lower vulnerability to contamination.

The map also includes information on the locations of selected observation wells. Available information on these observation wells is referenced in Appendix A, Description of the Logic in Factor Selection. Large man-made features such as landfills, quarries, or strip mines have also been marked on the map for reference.

GENERAL INFORMATION ABOUT GEAUGA COUNTY

Geauga County, Ohio lies within the Glaciated Central hydrogeologic region (Aller et. al., 1987). The entire county is covered by variable thicknesses of glacial till and outwash sand and gravel. The county is crossed by a network of buried valleys that constitute the major ground-water resource. Yields from the sand and gravel deposits in the buried valleys are quite variable but are significant in some areas. The remaining coarser-grained glacial deposits also may have substantial yields; yields from the tills are variable but typically low. These glacial deposits serve as the source of recharge to the underlying bedrock and are underlain predominantly by sandstone bedrock, sandstone, and shale sequences. Bedded sequences typically yield supplies sufficient for domestic use only; sandstone bedrock generally yields moderate supplies of ground-water.

In mapping Geauga County, eight (8) hydrogeologic settings were identified and included. Computed DRASTIC Index values range from 80 to 207. Table 10 details the settings and ranges of associated DRASTIC Indexes. Also noted in the table are the number of unique DRASTIC Index calculations that were made during the mapping effort. The DRASTIC Index numbers reflect evaluation of unconfined aquifers although semi-confined conditions may exist in parts of the county.

Physiography

Geauga County lies within the Southern New York Section of the Appalachian Plateau Province (Fenneman, 1938). Topography in the county ranges from gently rolling to steeply sloping. The steepest slopes are found along valley walls where some cliffs are 100 feet or more in height (Totten, 1988). The dominant topographic features within the county are numerous sandstone knobs and ridges, many surrounded by deep narrow valleys (Totten, 1988).

The North East Division of Ohio, which includes all of Geauga County, has a fifty year (1931-1980) average annual precipitation of 36.97 inches (U.S. Department of Commerce, 1981). The average annual temperature for the same period was 49.7 degrees Fahrenheit (U.S. Department of Commerce, 1981). For the thirty year period from 1961 through 1990 the Chardon U.S. Weather Bureau Station recorded an average annual precipitation of 45.63 inches (U.S. Department of Commerce, 1992). The 30 year (1961-1990) average annual temperature was 46.8 degrees Fahrenheit (U.S. Department of Commerce, 1992).

Figure 3. Location of Geauga County in Ohio.

The vast majority of Geauga County lies within the Lake Erie drainage basin. The principal streams flowing through the county include the Chagrin River and the Cuyahoga River. Only one small area in southeastern Troy township lies within the Ohio River basin.

Glacial GeologyGlacial Geology

During the Pleistocene Epoch (2 million to 10,000 years ago), at least four episodes of glaciation occurred in North America. In Ohio, evidence exists for three of these periods: the Wisconsinan, which occurred between 70,000 and 10,000 years ago; the Illinoian, which occurred at least 120,000 years ago, and the pre-Illinoian (Kansian). Approximately two thirds of the state is covered by a mantle of glacial material deposited during these periods (See Figure 3).

The majority of the glacial materials in Ohio were deposited by the Wisconsinan glaciers. Less extensive Illinoian-age deposits are found in the southwestern counties of the state along most of the glacial boundary. Pre-Illinoian (Kansan) deposits are evident at the surface only in Hamilton County. Glacial deposits in Ohio average 35 to 40 feet in thickness. However, thicknesses range from less than a foot to more than 500 feet (Stout et al., 1943).

Glacial till (Wisconsinan age) Covers most of Geauga County. Till, by definition, is deposited directly by glacial ice and is typically a poorly sorted mixture of clay, silt, sand, and gravel. The total thickness of all till layers in Geauga County ranges from less than 2 feet on the crest of some knobs and ridges, to several hundred feet in the deeper buried valleys (Totten, 1988).

The Defiance Moraine (a glacial end moraine) virtually surrounds the county on three sides: east, west, and north. This feature is composed primarily of glacial till with some gravel. Totten (1988), described the Defiance Moraine in Geauga County as "...a more or less continuous belt of hummocky topography, typically 1 to 2 miles wide with 10 to 30 feet of relief...". Other smaller end moraines or segments of end moraines can be found in Russell, Chester, Clairdon, Middlefield, and Parkman Townships (Totten, 1988). The end moraines in Geauga County have been interpreted as indicating the furthest extent of the advance of a glacier.

As glacial ice melts, a tremendous volume of water is released. This melt water carries with it sand, gravel, silt, and clay previously trapped within the glacial ice. The moving water sorts these materials by size, depositing the coarse sand and gravel near the source of the melt water and carrying away the silt and clay downstream. If the sand and gravel is deposited directly on the land surface in front of glacial ice the resulting formation is referred to as an "outwash deposit". If the sand and gravel was deposited in holes or depressions on the ice, and then laid down on the land surface as the ice melted, the resulting deposit is referred to as a "kame". In areas where ice remained in the valleys while the uplands were ice-free, meltwater often deposited sand and gravel that would sometimes accumulate in bands along the margins between the ice and the uplands. Deposits of this type are called "kame terraces".

Outwash deposits, kames and kame terraces are common in Geauga County. Outwash deposits found near the surface in the county are primarily confined to the valleys currently occupied by the larger streams which flow through the county (Totten, 1988).

Kames and kame terraces are also found within the valleys of the major streams. However, a large area (approximately 10 miles long and 5 miles wide) of kames and kame terraces covered by a layer of glacial till occurs in Auburn, Newbury, Munson, Burton, and Troy Townships (Totten, 1988).

Lacustrine (lake bottom) deposits are the surficial deposits within most of the Cuyahoga River valley and large parts of many of the other large river valleys. Layers of silt and fine sand are the primary components of these deposits. Surface runoff washed these sediments into lakes which occupied the valleys when glacial ice blocked the flow in the rivers. Over a period of time the silt and sand settled to the bottom of the lakes and accumulated into thick deposits. Lacustrine deposits also occur where kettle lakes have been filled in with sediments.

Buried ValleysBuried Valleys

Streams which flowed either prior to or between periods of glaciation cut deep valleys into the bedrock underlying Geauga County. The largest and deepest of these valleys form a network which trends northeast to southwest and northwest to southeast through the center of the county.

As glacial ice advanced through the county, flow in the streams ceased and the bedrock valleys were partially, and in some areas totally, filled with glacial drift. This material consists primarily of till but does contain some significant layers of outwash sand and gravel in many areas.

Bedrock GeologyBedrock Geology

Bedrock underlying Geauga County belongs to the Devonian, Mississippian and Pennsylvanian Systems (See Table 9). These formations are predominantly sandstones, conglomerates, and shale.

The Sharon Sandstone (Pennsylvanian System) is the predominant formation capping the numerous bedrock ridges and knobs in the northern third of the county (Hanson, unpublished). Most ridges and knobs in the southern two thirds are capped by either the Massillon Sandstone (Pennsylvanian System) or the Sharon Sandstone. Some ridges in the southwest corner of the county are capped by the Mercer Shale. Sugarloaf Mountain, the highest point in Geauga county, is capped by the Homewood Sandstone (Pennsylvanian System).

Bedrock within the buried stream channels are predominantly shales belonging to the Mississippian and Devonian Systems (Hanson, unpublished). The lowermost units in the shallower valleys are typically the Mississippian age Meadville Shale and Orangeville Shale while the lowermost units in the deeper valleys are the Cleveland Shale and the Chagrin Shale (Devonian System).

Hydrogeology Hydrogeology

Geauga County lies within the Glaciated Central hydrogeologic region of the DRASTIC system (Aller et al. 1987). The entire county is covered by variable thicknesses of glacial till and outwash sand and gravel. The thickest deposits are found in the areas underlain by buried valleys. The coarser-grained deposits constitute the major ground-water resource; yields from the till are variable but generally low. The glacial deposits also serve as the source of recharge to the underlying bedrock aquifers.

Aquifers within Geauga County are divided into two general groups: consolidated sandstone and shale formations within the bedrock, and unconsolidated glacial deposits. Of these two, the most wide-spread aquifers are the various bedrock formations. Bedrock aquifers on the ridges and hills are primarily the Sharon Conglomerate and the Massilon Sandstone. Yields from these formations may by as high as 100 gallons per minute in some locations (Walker, 1978). In the valleys and lowlands the principal bedrock aquifers are the interbedded sandstones and shales of the Mississippian System (See Table 9). Devonian-age shale is the uppermost aquifer in a small band along the northern edge of the county. Yields from this formation are typically small, usually barely enough for domestic needs.

Unconsolidated aquifers are found primarily within the buried valley areas. Outwash sand and gravel deposits in these valleys may yield more than 500 gallons per minute to large diameter wells (Walker, 1978). Other sand and gravel aquifers within the county include widely scattered kame deposits and alluvial deposits underlying the floodplains of some of the larger streams.

TABLE 9. GENERALIZED BEDROCK STRATIGRAPHY OF GEAUGA COUNTY, OHIO (Modified from: Bower 1951; Fuller 1965a; Pedry 1951; and Szmuck 1957).

SYSTEM	GROUP	FORMATION	ROCK TYPE
PENNSYLVANIAN	Pottsville	Homewood Sandstone	White to tan, medium- to coarse-grained sandstone
		Mercer Shale	Blue-gray to black, silty to sandy, micaceous shale, locally interbedded with sandstone or siltstone layers
		Massillon Sandstone	White to buff, fine- to medimum-grained sandstone, locally contains thin layers of shale
		Quakerstown Coal	Coal, found locally
		Sharon Shale	Blue-gray, sandy micaceous shale, may contain thin layers of siltstone and/or sandstone
		Sharom Coal	Coal, found locally
		Sharon Conglomerate	White, medium- to coarse-grained sandstone; contains lenses of pebbles
MISSISSIPPIAN		Meadville Shale	Interbedded blue-gray shales and siltstones
		Sharpsville Sandstone	Blue-gray siltstone
		Orangeville Shale	Blue-gray, silty shale with some siltstone layers
		Berea Sandstone	Gray to blue-gray, fine- to medium-grained sandstone
		Bedford Shale	Blue-gray, silty shale with thin interbedded siltstones
DEVONIAN	Cuyahoga	Ohio Shale: Cleveland Shale	Dark-gray to black shale
		Ohio Shale: Chagrin Shale	Blue-gray silty shale with some thin siltstone layers

REFERENCES

Aller, Linda and Ballou, Karen., 1991. Ground water pollution potential of Lake County, Ohio. Ohio Department of Natural Resources, Divison of Water, Report No. 8, 55 pp., 1 map.

Aller, Linda, Truman Bennett, Jay H. Lehr, Rebecca J. Petty and Glen Hackett, 1987. DRASTIC: A standardized system for evaluating ground-water pollution potential using hydrogeologic settings. United States Environmental Protection Agency Publication Number 600/2-87-035, 622 pp.

Barber, Douglas J., 1994. Ground water pollution potential of Cuyahoga County, Ohio. Ohio Department of Natural Resources, Division of Water, Report No. 4, 65 pp., 1 map.

Bower, Anita S., 1951. The stratigraphy and paleontology of the Cuyahoga formation of northern Ohio. Ohio State University Masters Thesis, Unpublished, 230 pp.

Bowernocker, J.A., 1965. Geologic map of Ohio. Ohio Department of Natural Resources, 1 map.

Cummins, Jack W., 1959. Buried river valleys in Ohio. Ohio Department of Natural Resources, Ohio Water Plan Inventory Report No. 10, 3 pp., 2 plates.

Eagon, Jr., H.B., No Date (a). Pumping test, winter sports area well, Punderson State Park. Geauga County, Unpublished, 2 pp. plus Attachments.

Eagon, Jr., H.B., No Date (b). Pumping tests, camping area wells, Punderson State Park. Geauga County, Unpublished, 2 pp. plus Attachments.

Fenneman, 1938. Physiography of the eastern United States. McGraw-Hill Pub. Co., New York, 714 pp.

Freeze, R. Allan and John A. Cherry, 1979. Groundwater. Prentice-Hall, Englewood Cliffs, New Jersey, pg. 29.

Fuller, J. Osborn, 1965a. Bedrock geology of the Garrettsville Quadrangle. Ohio Department of Natural Resources, Division of Geological Survey, Report of Investigations No. 54, 26 pp., 1 map.

Fuller, J. Osborn, 1965b. Source of Sharon conglomerate of northeastern Ohio. Bulletin of the Geological Society of America, Vol. 66, pp. 159-176.

Goldthwait, Richard P., George W. White and Jane L. Forsyth, 1967. Glacial map of Ohio. Ohio Geological Survey, I-316, 1 map.

Heath, R.C., 1984. Ground water regions of the United States. U.S. Geological Survey, Water Supply Paper 2242, 78 pp.

Moody and Associates, Inc., 1973a. Ground water development for Ravencrest Estates. Meadville, Pennsylvania, Unpublished, 7 pp. plus Appendix.

Moody and Associates, Inc., 1973b. Ground water development report, Arrowhead Farms, Geauga County, Ohio. Meadville, Pennsylvania, Unpublished, 9 pp. plus Appendix.

Moody and Associates, Inc., 1976. Ground water development, Village of Middlefield. Meadville, Pennsylvania, Unpublished, 14 pp. plus Appendix.

Ohio Department of Natural Resources, 1959. Water inventory of the Cuyahoga and Chagrin River Basins. Ohio Division of Water,, Ohio Water Plan Inventory No. 2, 90 pp., 1 map.

Ohio Drilling Company, 1971., Ground water pollution potential of northeast Ohio, Massillon, Ohio, 360 pp., 1 plate.

Ohio Environmental Protection Agency, 1986. Ohio ground water protection and management strategy. 67 pp.

Pedry, John J., 1951. The geology of Chagrin Falls Township, Cuyahoga County and Bainbridge Township, Geauga County, Ohio. Ohio State University Masters Thesis, Unpublished, 109 pp.

Rau, Jon L., 1969. Hydrogeology of the Berea and Cussewago sandstones in northeastern Ohio. U.S. Geological Survey Hydrologic Investigations Atlas HA-341, 2 maps with text.

Sedam, Alan C., 1973. Hydrogeology of the Pottsville formation in northeastern Ohio. U.S. Geological Survey Hydrologic Investigations Atlas HA-494, 2 maps with text.

Stout, W.S., Ver Steeg, K., and Lamb, G.F., 1943. Geology of water in Ohio. Ohio Department of Natural Resources, Division of Geological Survey, Bull. 44, 694 pp, 8 maps.

Szmuc, Eugene J, 1957. Stratigraphy and paleontology of the Cuyahoga formation of northern Ohio. Ohio State University Ph.D. Dissertation, Unpublished, 230 pp.

Tague, Glenn C., 1953. An artesian system in the Sharon conglomerate near Chardon, Ohio. The Ohio Journal of Science, Vol. 53, No. 6, pp. 343-346.

Totten, Stanley M., 1988. Glacial geology of Geauga County, Ohio. Ohio Department of Natural Resources, Division of Geological Survey, Report of Investigations No. 140, 30 pp., 1 plate.

United States Department of Commerce, 1981 a. Divisional normals and standard deviations of temperature (°F) and precipitation (Inches) 1931-80. National Oceanic and Atmospheric Administration, National Climate Center, Climatography of the United States No. 85, 175 pp., 1 map.

___________, 1992. Monthly station normals of temperature, precipitation, and heating, and cooling degree days 1961-1990, Ohio. National Oceanic and Atmospheric Administration, National Climate Center, Climatography of the United States No. 81.

Walker, Alfred C., 1978. Ground-water resources of Geauga County. Ohio Department of Natural Resources, Division of Water, 1 map.

Williams, N.L., F.E. McCleary, 1982. Soil survey of Geauga County, Ohio. United States Department of Agriculture, Soil Conservation Service, 169 pp., 53 maps.

UNPUBLISHED DATA

Ohio Department of Natural Resources. Division of Water, Ground Water Resources Section, well log completion reports for Geauga County.

Hanson, Mike. Ohio Department of Natural Resources, Division of Geological Survey, Geologist, per. comm.

APPENDIX A

DESCRIPTION OF THE LOGIC IN FACTOR SELECTION

Depth to Water

Water-level information was obtained by using located water well completion reports available at the Ohio Department of Natural Resources, Division of Water. All located wells were plotted and data were interpreted with respect to geology and topography.

Water levels in the county are extremely variable. However, in general, water levels average 15 to 30 feet (7) or 30 to 50 feet (5) throughout the county. Water levels along the rivers in the River Alluvium setting along the central portion of the Geauga-Ashtabula county line east and northeast of Montville and southeast of Huntsburg, south of East Branch Reservoir in an area adjacent to the Cuyahoga River, and in areas adjacent to the East Branch of the Chagrin and Chagrin Rivers average 5 to 15 feet (9). Water levels in the northeastern part of the county around Chesterland from the East Branch of the Chagrin to the Cuyahoga County line. In the southwestern corner of the county and in the northeaster corner bordering on Lake County are typically deeper than average and generally range between 50 to 75 feet (3). Isolated areas of the county along the Chagrin River east of Welshefield and in northern Thompson township have water levels that average 75 to 100 feet (2).

Net Recharge

Published references for net recharge were not located during reference-searching for this county. Net recharge rates were estimated based on precipitation and predicted infiltration due to geology, soils, and topography. Values of 4 to 7 inches per year (6) were assigned to the majority of the county recognizing that recharge most likely is in the lower portion of this range where glacial till deposits are thick. Where more permeable outwash deposits were delineated, values of 10+ inches per year (9) were chosen. River alluvium was assigned a value of 7 to 10 inches per year (8). Values of 4 to 7 inches per year (6), 7 to 10 inches per year (8), and 10+ inches per year (9) were chosen in the Buried Valleys based on the character of the overlying surficial deposits. Values of 2 to 4 inches per year (3) were assigned to areas of Glacial Till Over Shale and Buried Valleys adjacent to Cuyahoga County based on information obtained from Barber (1994).

Aquifer Media

Information on aquifer media was primarily derived from: Totten (1988), Walker (1978), Rau (1969), Sedam (1973), and well completion reports from the Ohio Department of Natural Resources, Division of Water. Additional information was gleaned from: Fuller (1965a and b), Ohio Department of Natural Resources (1959), Pedry (1951), Szmuc (1957), Bower (1951), Tague (1953), Moody and Associates (1973a, 1973b, 1976), the Ohio Drilling Company (1971), Cummins (1959), Bownocker (1965), and Goldthwait et al. (1967).

Although the county is covered by variable thicknesses of unconsolidated deposits, the aquifer chosen for the majority of the county is the underlying bedrock. In Glacial Till Over Bedded Sedimentary Rocks, the underlying sequences of sandstone and shale were chosen as the aquifer and assigned a value of (6). In Glacial Till Over Sandstone, the underlying sandstone was chosen as the aquifer and assigned a value of (6). Glacial Till Over Shale occurs in a small band along the northern edge of the county. In these areas, the underlying shale was chosen as the aquifer where the unconsolidated deposits are thin and assigned a value of (2). Where the unconsolidated deposits are thicker than 25 feet, the glacial till was chosen as the aquifer and assigned a value of (5). Where Glacial Lake Deposits were designated, the underlying sandstone bedrock and sandstone/shale sequences were chosen as the aquifer in outwash areas. Where the deposits were noted as kames, a value of (9) was assigned because of the abundance of coarser-grained material; a value of (8) was assigned in the terrace deposit areas. In the alluvium along the rivers, sand and gravel was chosen as the aquifer and assigned a typical value of (8). In areas where alluvium occurs along tributaries, the underlying bedrock was chosen as the aquifer. In these areas, bedded sandstone, limestone, and shale sequences as well as sandstone were assigned a value of (6). Along the Chagrin River flowing into Cuyahoga County, the underlying sandstone was assigned a value of (4) based on information found in Barber (1994). Sand and gravel was chosen as the aquifer in the Buried Valleys; typical values of (8) were assigned to the majority of the areas. Where kame deposits were indicated, a value of (9) was assigned because of the abundance of coarse-grained material. In buried valley areas adjacent to Cuyahoga County, sand and gravel was assigned a value of (5) based on information found in Barber (1994). In buried valley areas adjacent to Lake County, sand and gravel was assigned a value of (6) based on information found in Aller and Ballou (1991).

<u>Soil Media</u>

Soils were mapped based on the soil survey of Geauga County (Williams And McCleary, 1982). The soil media were assigned using the general soil association map in approximately 80 percent of the county; the remainder was re-mapped using DRASTIC-based parameters. Soils formed in glacial till are predominantly silty loam (4) with areas of clay loam (3) in the southeastern corner, east central, and north central parts of the county. Gravel (10) predominates along the rivers and creeks, with loam (5) soils directly adjacent to the gravel soils. Shrinking clay (7) soils occur in the southeastern corner of the county, along the Geauga-Trumbull County line. Soils found northeast of Bass Lake, surrounding and between Snow Lake and Lake Kelso, and along the northeastern branch of the Cuyahoga River are designated as muck (2).

<u>Topography</u>

Percent slope was estimated by using 7 1/2 minute USGS topographic Quadrangle maps. Contour intervals on the topographic maps are 10 feet on all quadrangles. Topography averages 2 to 6 percent (9) in the majority of the county, although areas of 0 to 2 percent (10) are also common. One area of 6 to 12 percent (5) slope occurs in northeastern Russell Township adjacent to the Chagrin River and another occurs in southwestern Bainbridge

Township. Slopes of 12 to 18 percent (3) and 18+ percent (1) occur along river valleys, primarily in the northern and western parts of the county.

Vadose Zone Media

Information on the vadose zone media was primarily obtained from: Totten (1988), Rau (1969), Sedam (1973), and well completion reports form the Ohio Department of Natural Resources. Additional information was gleaned from: Tague (1953), Bower (1951), Szmuc (1957), Pedry (1951), and Fuller (1965a).

Thicknesses of unconsolidated deposits are extremely variable throughout the county. Where till-rich deposits are significant from a pollution potential standpoint, the silt/clay designation was chosen as the vadose zone media in the Glacial Till Over Bedded Sedimentary Rocks, Glacial Till Over Sandstone, and Glacial Till Over Shale settings. Where the surficial deposits were designated Hiram Till, a value of (4) was assigned; where Kent Till was indicated in the central portion of the county, value of (6) was assigned to reflect the higher sand content; where Lavery Till was designated adjacent to Lake County a value of (5) was assigned. The designation of sand and gravel with significant silt and clay was assigned a value of (4) and used in Glacial Till Over Sandstone areas adjacent to Cuyahoga County based on information found in Barber (1994). Where glacial deposits are thin and/or water levels deeper, bedded sandstone, limestone, and shale sequences (6); sandstone (6); and shale (3) were chosen as the vadose zone media. In areas where surficial deposits were designated as lake plains, the designation of silt/clay was chosen and assigned a value of (5). Sand and gravel was chosen as the vadose zone media in the outwash areas. A value of (9) was assigned where kames were designated and a value of (8) was assigned in the terrace areas. The vadose zone media in the river alluvium was designated as sand and gravel with significant silt and clay and assigned a typical value of (6) based on the amount of fines usually found in those deposits. Along the Chagrin River where it flows into Cuyahoga County, the sand and gravel with significant silt and clay designation was assigned a value of (5) based on information found in Barber (1994). In the buried valley areas, the vadose zone media was chosen based on the type of overlying deposit. The vadose zone media ranged from sand and gravel (8) and (9) in areas of terrace deposits and kames respectively to silt/clay (4) and (5) in Hiram Till and lake plains respectively to sand and gravel with significant silt and clay (4), (6) and (7) representing various fractions of fines in the deposits.

Hydraulic Conductivity

Only limited published data on the hydraulic conductivity of the sandstone bedrock were found for this County in Sedam (1973). Values of hydraulic conductivity were primarily estimated by reading descriptions in Walker (1978), referring to unpublished values in Moody and Associates (1973a, 1973b and 1976) and Eagon (No date (a) and (b) and referring to the appropriate values referenced by Freeze and Cherry (1979). Values of 300 to 700 gallons per day per square foot (4) were assigned to the sandstone bedrock based on information in Sedam (1973) except along the Cuyahoga border where values of 1 to 100 gallons per day per square foot (1) were assigned based on information found in Barber (1994). Values of 100 to 300 gallons per day per square foot (2) were assigned to the bedded sandstone/shale areas based on anticipated yields in Walker (1978). Values of 1 to 100 gallons per day per square foot (1) were assigned along the Lake County border based on information found in Aller and Ballou (1991). In areas where shale bedrock was designated as the aquifer, values of 1 to 100 gallons per day per square foot (1) were assigned. Values of 100 to 300 gallons per day per square foot (2), 300 to 700 gallons per day per square foot (4), 700 to 1000 gallons per day per square foot (6) and 1000 to 2000 gallons per day per square foot (8) were assigned in the buried valley areas based on anticipated yields in Walker (1978) and the character of the aquifer. Outwash deposits were estimated to have values of 1000 to 2000 gallons per day per square foot (8) based on their coarser nature. River alluvium was estimated to have values of 700 to 1000 gallons per day per square foot (6) except along the Chagrin River adjacent to Cuyahoga County where 1 to 100 gallons per day per square foot (1) was assigned based on information found in Barber (1994).

APPENDIX B

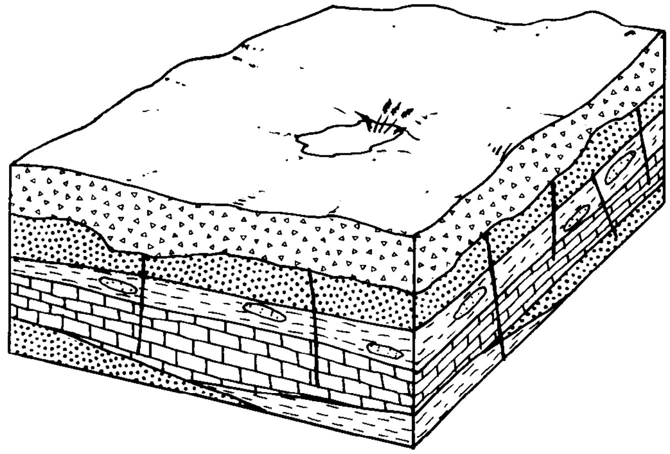
DESCRIPTION OF HYDROGEOLOGIC SETTINGS AND CHARTS

Ground water pollution potential mapping in Geauga County resulted in the identification of eight hydrogeologic settings within the Glaciated Central Region. The list of these settings, the range of pollution potential index calculations, and the number of index calculations for each setting are provided in Table 10. Computed pollution potential indexes for Geauga County range from 80 to 207.

TABLE 10. HYDROGEOLOGIC SETTINGS MAPPED IN GEAUGA COUNTY, OHIO.

Hydrogeologic Settings	Range of GWPP Indexes	Number of Index Calculations
7Aa - Glacial Till Over Bedded Sedimentary Rock	104 - 153	30
7Ad - Glacial Till Over Sandstone	95 - 148	23
7Ae - Glacial Till Over Shale	80 - 129	15
7Ba - Outwash	155 - 206	10
7Bb- Outwash Over Bedded Sedimentary Rock	179 - 189	2
7D - Buried Valley	87 - 207	28
7Eb - River Alluvium Without Overbank Deposits	131 - 179	15
7F - Glacial Lake Deposits	116 - 144	5

The following information provides a description of each hydrogeologic setting identified in the county, a block diagram illustrating the characteristics of the setting, and a listing of the charts for each unique combination of pollution potential indexes calculated for each setting. The charts provide information on how the ground water pollution potential index was derived and are a quick and easy reference for the accompanying ground water pollution potential map. A complete discussion of the rating and evaluation of each factor in the hydrogeologic settings is provided in Appendix A, Description of the Logic in Factor Selection.



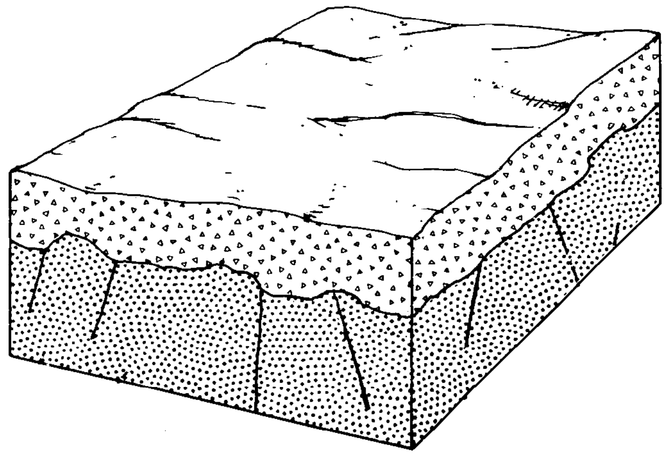
7Aa Glacial Till Over Bedded Sedimentary Rock

This hydrogeologic setting is characterized by high relief with prominent, steep-sided ridges, and by relatively flat-lying, fractured sedimentary rocks. The rocks are predominantly sandstones with thin, inter-layered coals and shales which are covered by varying thicknesses of glacial till. The thin coal seams are usually highly fractured and are quite permeable. Thin clay and shale zones tend to impede vertical water movement and create "perched " water tables. The till is basically an unsorted deposit which contains localized deposits of sand and gravel. Although precipitation is abundant in the region, recharge is generally moderate due to the relatively high depth to water (low water table) and the corresponding thick vadose zone composed of compacted tills. Depth to water is variable, but generally ranges between 25 to 50 feet.

GWPP index values for the hydrogeologic setting of glacial till over bedded sedimentary rocks range from 104-153 with the total number of GWPP index calculations equaling 30.

Setting	Depth to Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pest Rating
7Aa01	15-30	4-7	Bedded SS, LS, & SH Sequences	Silty Loam	2-6	Silt/Clay	100-300	120	144
7Aa02	15-30	4-7	Bedded SS, LS, & SH Sequences	Clay Loam	2-6	Bedded SS, LS, SH, Sequences	100-300	128	147
7Aa03	30-50	4-7	Bedded SS, LS, & SH Sequences	Silty Loam	2-6	Silt/Clay	100-300	110	134
7Aa04	15-30	4-7	Bedded SS, LS, & SH Sequences	Gravel	6-12	Silt/Clay	100-300	128	162
7Aa05	15-30	4-7	Bedded SS, LS, & SH Sequences	Silty Loam	0-2	Bedded SS, LS, SH, Sequences	1-100	128	153
7Aa06	15-30	4-7	Bedded SS, LS, & SH Sequences	Thin or Absent	2-6	Bedded SS, LS, SH, Sequences	100-300	142	182
7Aa07	30-50	4-7	Bedded SS, LS, & SH Sequences	Clay Loam	6-12	Bedded SS, LS, SH, Sequences	100-300	114	125
7Aa08	5-15	4-7	Bedded SS, LS, & SH Sequences	Silty Loam	6-12	Bedded SS, LS, SH, Sequences	100-300	136	150

Setting	Depth to Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pest Rating
7Aa09	50-75	4-7	Bedded SS, LS, & SH Sequences	Clay Loam	6-12	Bedded SS, LS, SH, Sequences	100-300	104	115
7Aa10	30-50	4-7	Bedded SS, LS, & SH Sequences	Silty Loam	2-6	Bedded SS, LS, SH, Sequences	100-300	120	142
7Aa11	5-15	4-7	Bedded SS, LS, & SH Sequences	Silty Loam	0-2	Bedded SS, LS, SH, Sequences	1-100	138	163
7Aa12	5-15	4-7	Bedded SS, LS, & SH Sequences	Sandy Loam	2-6	Silt/Clay	100-300	134	164
7Aa13	30-50	4-7	Bedded SS, LS, & SH Sequences	Silty Loam	6-12	Silt/Clay	100-300	106	122
7Aa14	30-50	4-7	Bedded SS, LS, & SH Sequences	Gravel	2-6	Silt/Clay	100-300	122	164
7Aa15	50-75	4-7	Bedded SS, LS, & SH Sequences	Silty Loam	2-6	Bedded SS, LS, SH, Sequences	100-300	110	132
7Aa16	30-50	4-7	Bedded SS, LS, & SH Sequences	Sandy Loam	2-6	Silt/Clay	100-300	114	144
7Aa17	30-50	4-7	Bedded SS, LS, & SH Sequences	Sandy Loam	2-6	Bedded SS, LS, SH, Sequences	100-300	124	152
7Aa18	15-30	4-7	Bedded SS, LS, & SH Sequences	Clay Loam	2-6	Silt/Clay	100-300	118	139
7Aa19	5-15	4-7	Bedded SS, LS, & SH Sequences	Thin or Absent	0-2	Bedded SS, LS, SH, Sequences	100-300	153	195
7Aa20	5-15	4-7	Bedded SS, LS, & SH Sequences	Gravel	0-2	Silt/Clay	100-300	143	187
7Aa21	30-50	4-7	Bedded SS, LS, & SH Sequences	Clay Loam	2-6	Silt/Clay	100-300	108	129
7Aa22	15-30	4-7	Bedded SS, LS, & SH Sequences	Shrinking and/or Aggregated Clay	2-6	Silt/Clay	100-300	126	159
7Aa23	5-15	4-7	Bedded SS, LS, & SH Sequences	Silty Loam	0-2	Silt/Clay	100-300	131	157
7Aa24	15-30	4-7	Bedded SS, LS, & SH Sequences	Silty Loam	0-2	Silt/Clay	100-300	121	147
7Aa25	15-30	4-7	Bedded SS, LS, & SH Sequences	Gravel	2-6	Silt/Clay	100-300	132	174
7Aa26	5-15	4-7	Bedded SS, LS, & SH Sequences	Sandy Loam	2-6	Bedded SS, LS, SH, Sequences	100-300	144	172
7Aa27	15-30	4-7	Bedded SS, LS, & SH Sequences	Silty Loam	2-6	Bedded SS, LS, SH, Sequences	100-300	130	152
7Aa28	15-30	4-7	Till	Silty Loam	0-2	Silt/Clay	1-100	115	142
7Aa29	15-30	4-7	Bedded SS, LS, & SH Sequences	Silty Loam	2-6	Bedded SS, LS, SH, Sequences	1-100	127	150
7Aa30	15-30	4-7	Bedded SS, LS, & SH Sequences	Silty Loam	0-2	Bedded SS, LS, SH, Sequences	1-100	128	153



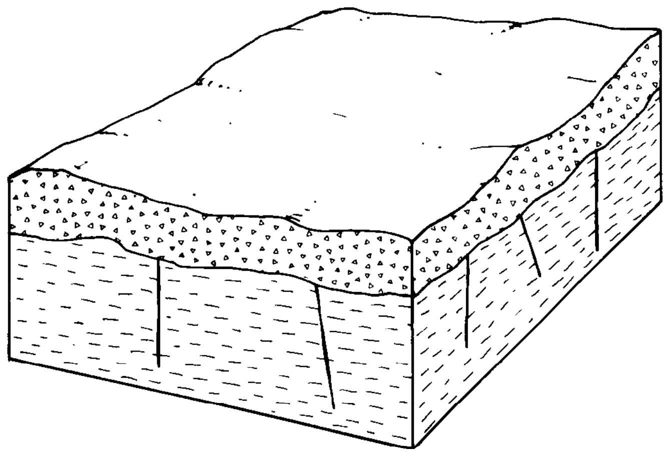
7Ad Glacial Till Over Sandstone

This hydrologic setting is characterized by low topography and relatively flat-lying, fractured sandstones which are covered by varing thicknesses of glacial till. The till is principally unsorted deposits which may be interbedded with loess or localized deposits of sand and gravel. Although ground water occurs in both the glacial deposits and in the intersecting bedrock fractures, the bedrock is typically the principal aquifer. The glacial till serves as a source of recharge to the underlying bedrock. Although precipitation is abundant in most of the region, recharge is moderate because of the glacial tills which typically weather to clay loam. Depth to water is extremely variable, depending in part on the thickness of the glacial till, but averages around 40 feet.

GWPP index values for the hydrogeologic setting of glacial till over sandstone range from 95-148 with the total number of GWPP index calculations equaling 23.

Setting	Depth to Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pest Rating
7Ad01	30-50	4-7	Sandstone	Clay Loam	0-2	Silt/Clay	1-100	95	129
7Ad02	15-30	4-7	Sandstone	Clay Loam	0-2	Silt/Clay	1-100	110	134
7Ad03	15-30	4-7	Sandstone	Clay Loam	2-6	Sandstone	300-700	134	151
7Ad04	15-30	4-7	Sandstone	Clay Loam	2-6	Silt/Clay	300-700	124	143
7Ad05	30-50	4-7	Sandstone	Clay Loam	2-6	Sandstone	300-700	124	141
7Ad06	30-50	4-7	Sandstone	Silty Loam	2-6	Sandstone	300-700	126	146
7Ad07	15-30	4-7	Sandstone	Silty Loam	2-6	Silt/Clay	300-700	126	148
7Ad08	15-30	4-7	Sandstone	Sandy Loam	2-6	Sandstone	300-700	140	166
7Ad09	15-30	4-7	Sandstone	Clay Loam	6-12	Sand & Gravel w/sig Silt/Clay	1-100	105	119
7Ad10	50-75	4-7	Sandstone	Clay Loam	2-6	Silt/Clay	300-700	104	123
7Ad11	50-75	4-7	Sandstone	Silty Loam	2-6	Silt/Clay	300-700	103	125
7Ad12	30-50	4-7	Sandstone	Sandy Loam	2-6	Sandstone	300-700	130	156
7Ad13	15-30	4-7	Sandstone	Clay Loam	2-6	Silt/Clay	1-100	109	131
7Ad14	30-50	4-7	Sandstone	Thin or Absent	2-6	Sandstone	300-700	138	176
7Ad15	15-30	4-7	Sandstone	Thin or Absent	2-6	Sandstone	300-700	148	186

Setting	Depth to Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pest Rating
7Ad16	15-30	4-7	Sandstone	Gravel	2-6	Sand & Gravel w/sig Silt/Clay	300-700	138	178
7Ad17	5-15	4-7	Sandstone	Loam	2-6	Sandstone	300-700	148	171
7Ad18	15-30	4-7	Sandstone	Loam	2-6	Sandstone	300-700	138	161
7Ad19	75-100	4-7	Sandstone	Loam	2-6	Sandstone	300-700	113	136
7Ad20	5-15	4-7	Sandstone	Silty Loam	2-6	Silt/Clay	300-700	136	158
7Ad21	30-50	4-7	Sandstone	Clay Loam	0-2	Sand & Gravel w/sig Silt/Clay	1-100	100	124
7Ad22	50-75	4-7	Sandstone	Clay Loam	2-6	Sandstone	300-700	114	131
7Ad23	15-30	4-7	Sandstone	Loam	2-6	Silt/Clay	300-700	138	161

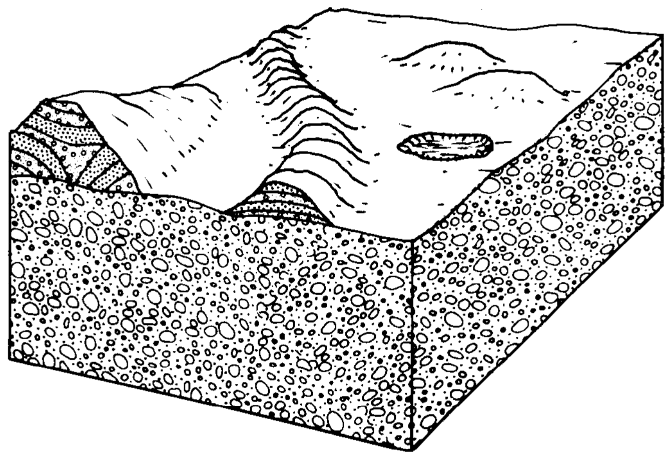


7Ae Glacial Till over Shale

This hydrogeologic setting is similar to (7Ad) Glacial Till Over Sandstone except that varying thicknesses of till overlie fractured, flat-lying shales. The till is principally unsorted deposits with interbedded lenses of loess and sand and gravel. Ground water is derived from either localized sources in the overlying till or from deeper, more permeable formations. The shale is relatively impermeable and does not serve as a source of ground water. Although precipitation is abundant, recharge is minimal from the till to deeper formations and occurs only by leakage of water through the fractures.

GWPP index values for the hydrogeologic setting of glacial till over shale range from 80-129 with the total number of GWPP index calculations equaling 15.

Setting	Depth to Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pest Rating
7Ae01	15-30	2-4	Shale	Silty Loam	18+	Silt/Clay	1-100	85	94
7Ae02	15-30	2-4	Shale	Clay Loam	18+	Silt/Clay	1-100	83	89
7Ae03	5-15	4-7	Shale	Silty Loam	0-2	Silt/Clay	1-100	116	143
7Ae04	30-50	4-7	Till	Silty Loam	18+	Silt/Clay	1-100	101	109
7Ae05	5-15	4-7	Shale	Silty Loam	2-6	Shale	1-100	110	136
7Ae06	5-15	4-7	Shale	Sandy Loam	2-6	Shale	1-100	114	146
7Ae07	15-30	4-7	Till	Sand	2-6	Silt/Clay	1-100	129	168
7Ae08	15-30	4-7	Till	Sand	18+	Sand & Gravel w/sig Silt/Clay	1-100	116	140
7Ae09	50-75	4-7	Shale	Silty Loam	2-6	Shale	1-100	80	106
7Ae10	50-75	4-7	Till	Silty Loam	2-6	Silt/Clay	1-100	94	119
7Ae11	75-100	4-7	Till	Silty Loam	18+	Silt/Clay	1-100	81	90
7Ae12	5-15	4-7	Shale	Loam	18+	Silt/Clay	1-100	114	125
7Ae13	5-15	4-7	Shale	Silty Loam	0-2	Shale	1-100	111	139
7Ae14	5-15	4-7	Shale	Silty Loam	18+	Shale	1-100	102	112
7Ae15	15-30	4-7	Shale	Loam	18+	Silt/Clay	1-100	104	115

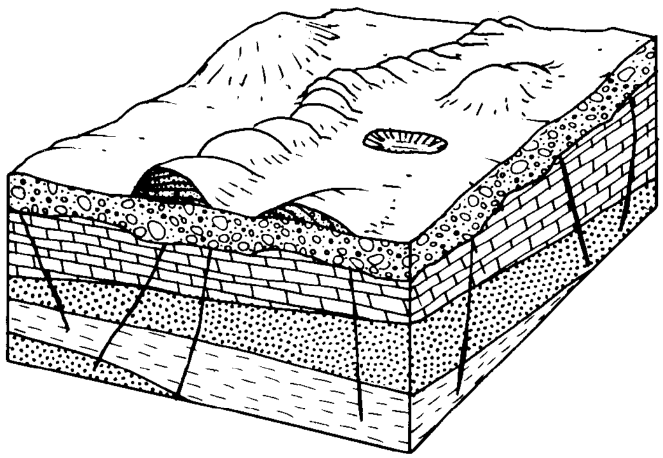


7Ba Outwash

This hydrogeologic setting is characterized by the rolling, hummocky, "kame and kettle" topography primarily associated with the Kent Kame Complex and Kent Moraine. Outwash deposits include ice-contact derived kames, depressional kettles and bogs, outwash plains, and channeled outwash valley trains associated with the stagnation of the Late Wisconsinan Kent Till. Outwash deposits typically overlie buried valleys; in some areas they overlie fractured sedimentary rocks. These deposits contain varying amounts of till and finer silty deposits which may somewhat impede recharge. Sands and gravels serve as the aquifer; the nature and extent of such units is highly variable. Recharge is moderate to high and soils are typically loams or sandy loams with peat or clay occurring in the depressions and kettles. Water levels are highly variable but generally range between 20 and 40 feet. The depth to water is greater for the more prominent kames and is usually shallower near kettles. These deposits may be in direct hydraulic connection with underlying, fractured bedrock.

GWPP index values for the hydrogeologic setting of outwash range from 155-206 with the total number of GWPP index calculations equaling 10.

Setting	Depth to Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pest Rating
7Ba01	15-30	10+	Sand & Gravel	Gravel	2-6	Sand & Gravel	1000-2000	196	227
7Ba02	30-50	10+	Sand & Gravel	Gravel	2-6	Sand & Gravel	1000-2000	186	217
7Ba03	30-50	10+	Sand & Gravel	Silty Loam	2-6	Sand & Gravel	1000-2000	174	187
7Ba04	5-15	10+	Sand & Gravel	Gravel	2-6	Sand & Gravel	1000-2000	206	237
7Ba05	15-30	10+	Sand & Gravel	Loam	2-6	Sand & Gravel	1000-2000	186	202
7Ba06	15-30	10+	Sand & Gravel	Clay Loam	0-2	Sand & Gravel	1000-2000	183	195
7Ba07	50-75	10+	Sand & Gravel	Silty Loam	2-6	Sand & Gravel	1000-2000	164	177
7Ba08	15-30	10+	Sand & Gravel	Sandy Loam	2-6	Sand & Gravel	1000-2000	188	207
7Ba09	5-15	10+	Sand & Gravel	Loam	2-6	Sand & Gravel	1000-2000	196	212
7Ba10	30-50	10+	Sandstone	Loam	2-6	Sand & Gravel	300-700	155	175

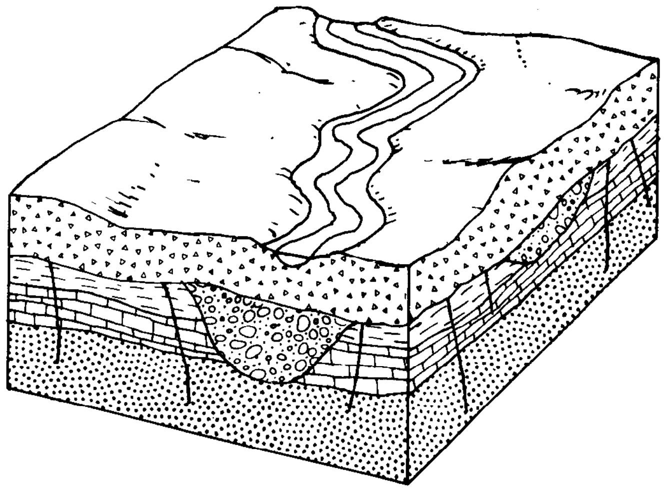


7Bb Outwash over Bedded Sedimentary Rocks

This hydrogeologic setting is characterized by low to moderate relief and overlies fractured sandstone or interbedded sandstone and shale sequences. Deposits include both valley train outwash as well as kame fields. The outwash is composed of sand and gravel and includes some incorporated zones of till. The sands and gravels in this setting are generally not as coarse, clean, or as well sorted as those in the 7Ba, Outwash setting. The depth to bedrock is also much shallower than in the 7D, Buried Valley, setting. Where the outwash deposits fine appreciably, a number of the wells may be developed in the underlying bedrock. Depth to water varies considerably with the high relief areas possessing greater depths to water and flat-lying stream valleys having shallow depths to water. Recharge is moderate and depends upon the amount of till cover. Soils range from clay loam to loam depending upon the thickness and nature of the till cover. These deposits may be in direct hydrologic connection with the underlying bedrock.

GWPP index values for the hydrogeologic setting of outwash over bedded sedimentary rock range from 179-189 with the total number of GWPP index calculations equaling 2.

Setting	Depth to Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pest Rating
7Bb01	15-30	10+	Sand & Gravel	Loam	0-2	Sand & Gravel	1000-2000	179	198
7Bb02	15-30	10+	Sand & Gravel	Gravel	0-2	Sand & Gravel	1000-2000	189	223



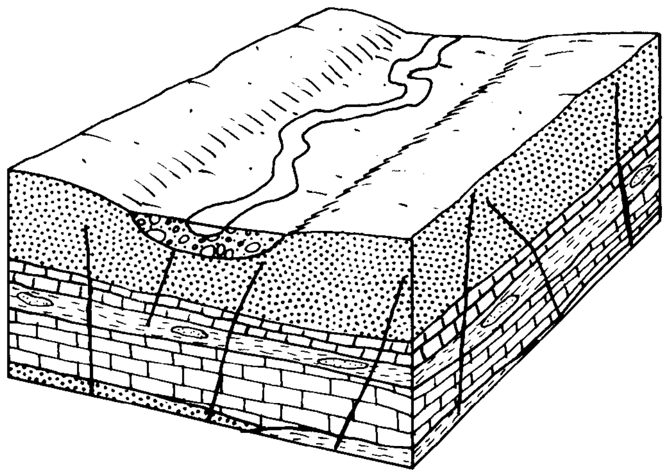
7D Buried Valleys

This hydrogeologic setting is characterized by thick deposits of sand and gravel that have been deposited in a former topographic low (usually a pre-glacial river valley) by glacial meltwaters. These deposits are capable of yielding large quantities of ground water. The deposits may or may not underlie a present-day river and may or may not be in direct hydraulic connection with a stream. Glacial till or recent alluvium often overlies the buried valley. Usually the deposits are several times more permeable than the surrounding bedrock. Soils are typically a sandy loam. Recharge to the sand and gravel is moderate and water levels are commonly relatively shallow, although they may be quite variable.

GWPP index values for the hydrogeologic setting of buried valley range from 87-207 with the total number of GWPP index calculations equaling 28.

Setting	Depth to Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pest Rating
7D01	30-50	2-4	Sand & Gravel	Silty Loam	18+	Silt/Clay	100-300	87	95
7D02	5-15	7-10	Sand & Gravel	Gravel	0-2	Sand & Gravel w/sig Silt/Clay	700-1000	179	217
7D03	30-50	4-7	Sand & Gravel	Silty Loam	6-12	Silt/Clay	300-700	118	132
7D04	15-30	4-7	Sand & Gravel	Silty Loam	2-6	Silt/Clay	300-700	132	154
7D05	50-75	4-7	Sand & Gravel	Silty Loam	0-2	Silt/Clay	300-700	113	137
7D06	5-15	10+	Sand & Gravel	Gravel	0-2	Sand & Gravel	1000-2000	207	240
7D07	75-100	4-7	Sand & Gravel	Clay Loam	2-6	Silt/Clay	300-700	105	124
7D08	30-50	10+	Sand & Gravel	Silty Loam	2-6	Sand & Gravel	1000-2000	174	187
7D09	50-75	4-7	Sand & Gravel	Silty Loam	2-6	Silt/Clay	300-700	112	134
7D10	50-75	4-7	Sand & Gravel	Clay Loam	0-2	Sand & Gravel w/sig Silt/Clay	100-300	96	119
7D11	15-30	4-7	Sand & Gravel	Clay Loam	0-2	Sand & Gravel w/sig Silt/Clay	100-300	116	139
7D12	50-75	4-7	Sand & Gravel	Silty Loam	0-2	Silt/Clay	100-300	101	127
7D13	5-15	4-7	Sand & Gravel	Muck	0-2	Silt/Clay	700-1000	150	165

Setting	Depth to Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pest Rating
7D14	30-50	10+	Sand & Gravel	Silty Loam	0-2	Sand & Gravel	1000-2000	167	183
7D15	15-30	7-10	Sand & Gravel	Gravel	2-6	Sand & Gravel	1000-2000	192	223
7D16	5-15	7-10	Sand & Gravel	Silty Loam	0-2	Sand & Gravel w/sig Silt/Clay	100-300	154	177
7D17	5-15	4-7	Sand & Gravel	Silty Loam	0-2	Silt/Clay	1000-2000	160	179
7D18	5-15	4-7	Sand & Gravel	Sandy Loam	0-2	Silt/Clay	700-1000	158	185
7D19	15-30	4-7	Sand & Gravel	Shrinking and/or Aggregated Clay	2-6	Silt/Clay	300-700	138	169
7D20	50-75	4-7	Sand & Gravel	Clay Loam	2-6	Silt/Clay	300-700	110	129
7D21	15-30	4-7	Sand & Gravel	Sandy Loam	2-6	Silt/Clay	300-700	136	164
7D22	30-50	4-7	Sand & Gravel	Silty Loam	2-6	Silt/Clay	700-1000	128	148
7D23	5-15	4-7	Sand & Gravel	Muck	0-2	Silt/Clay	700-1000	145	161
7D24	15-30	4-7	Sand & Gravel	Gravel	0-2	Silt/Clay	700-1000	156	195
7D25	30-50	10+	Sand & Gravel	Silty Loam	2-6	Sand & Gravel	100-300	147	166
7D26	5-15	7-10	Sand & Gravel	Sandy Loam	0-2	Sand & Gravel w/sig Silt/Clay	700-1000	171	197
7D27	75-100	4-7	Sand & Gravel	Silty Loam	18+	Silt/Clay	100-300	87	95
7D28	5-15	4-7	Sand & Gravel	Gravel	0-2	Silt/Clay	700-1000	166	205



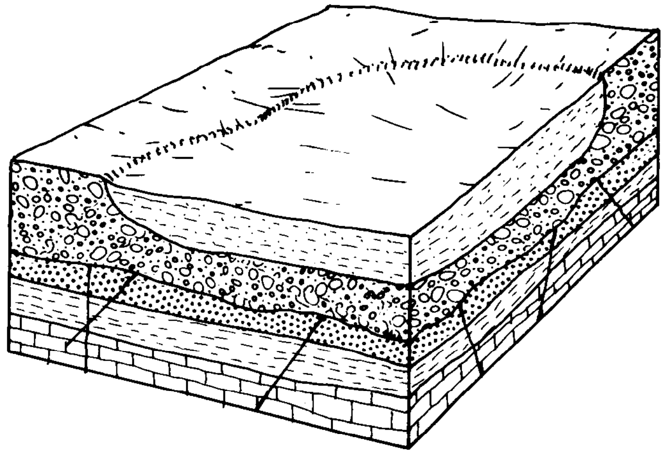
7Eb River Alluvium Without Overbank Deposits

This hydrogeologic setting is characterized by flat-lying topography along the floodplains of some moderate-sized streams. Moderately thick, relatively coarse alluvium is found within theses stream valleys. Theses valleys lack significant fine-grained overbank deposits. Recharge is relatively high and the depth to water is less then 15 feet. The coarse alluvium (sand and gravel) aquifer is commonly in direct hydrologic contact with the surface stream. The alluvium may also serve as a source of recharge to the underlying, fractured, sedimentary rocks.

GWPP index values for the hydrogeologic setting of river alluvium without overbank deposits range from 131-179 with the total number of GWPP index calculations equaling 15.

Setting	Depth to Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pest Rating
7Eb01	5-15	4-7	Sandstone	Sandy Loam	0-2	Sand & Gravel w/sig Silt/Clay	1-100	131	163
7Eb02	5-15	7-10	Sand & Gravel	Gravel	0-2	Sand & Gravel w/sig Silt/Clay	700-1000	179	217
7Eb03	5-15	7-10	Sandstone	Clay Loam	0-2	Sand & Gravel w/sig Silt/Clay	300-700	153	172
7Eb04	5-15	7-10	Bedded SS, LS, & SH Sequences	Clay Loam	0-2	Sand & Gravel w/sig Silt/Clay	100-300	147	168
7Eb05	5-15	7-10	Bedded SS, LS, & SH Sequences	Sandy Loam	0-2	Sand & Gravel w/sig Silt/Clay	100-300	153	183
7Eb06	5-15	7-10	Bedded SS, LS, & SH Sequences	Silty Loam	0-2	Sand & Gravel w/sig Silt/Clay	100-300	149	173
7Eb07	5-15	7-10	Sandstone	Silty Loam	0-2	Sand & Gravel w/sig Silt/Clay	300-700	155	177
7Eb08	5-15	7-10	Sandstone	Loam	0-2	Sand & Gravel w/sig Silt/Clay	300-700	157	182
7Eb09	5-15	7-10	Sand & Gravel	Clay Loam	0-2	Sand & Gravel w/sig Silt/Clay	700-1000	165	182
7Eb10	5-15	7-10	Sand & Gravel	Shrinking &/or Aggregated Clay	0-2	Sand & Gravel w/sig Silt/Clay	700-1000	173	202

Setting	Depth to Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pest Rating
7Eb11	5-15	7-10	Sandstone	Gravel	0-2	Sand & Gravel w/sig Silt/Clay	300-700	167	207
7Eb12	5-15	7-10	Sand & Gravel	Sandy Loam	0-2	Sand & Gravel w/sig Silt/Clay	700-1000	171	197
7Eb13	5-15	7-10	Bedded SS, LS, & SH Sequences	Gravel	0-2	Sand & Gravel w/sig Silt/Clay	100-300	161	203
7Eb14	5-15	7-10	Sand & Gravel	Silty Loam	0-2	Sand & Gravel w/sig Silt/Clay	700-1000	167	187
7Eb15	5-15	7-10	Shale	Silty Loam	0-2	Sand & Gravel w/sig Silt/Clay	1-100	129	155
7Eb16	5-15	4-7	Sand & Gravel	Silty Loam	0-2	Sand & Gravel w/sig Silt/Clay	700-1000	167	179



7F Glacial Lake Deposits

This hydrogeologic setting is characterized by flat topography and varying thicknesses of fine-graned sediments that overlie sequences of fractured sedimentary rocks. The deposits are composed of fine-grained silts and clays interlayered with fine sand that settled out in glacial lakes and exhibit alternating layers relating to seasonal fluctuations. As a consequence of the thin, alternating layers there is a substantial difference between the vertical and horizontal permeability with the horizontal commonly two or more orders of magnitude greater than the vertical. Due to their fine-grained nature, these deposits typically weather to organic-rich sandy loam with a range in permeabilities reflecting variations in sand content. Underlying glacial deposits or bedrock serve as the major source of ground water in the region. Although precipitation is abundant, recharge is controlled by the permeability of the surface clays; however, in all instances recharge is moderately high because of the impact of the low topography. Water levels are variable, depending on the thickness of the lake sediments and the underlying materials.

GWPP index values for the hydrogeologic setting of glacial lake deposits range from 116-144 with the total number of GWPP index calculations equaling 5.

Setting	Depth to Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pest Rating
7F01	15-30	4-7	Bedded SS, LS, & SH Sequences	Silty Loam	0-2	Silt/Clay	100-300	126	151
7F02	30-50	4-7	Bedded SS, LS, & SH Sequences	Silty Loam	0-2	Silt/Clay	100-300	116	141
7F03	15-30	4-7	Bedded SS, LS, & SH Sequences	Sandy Loam	0-2	Silt/Clay	100-300	130	161
7F04	15-30	4-7	Sandstone	Gravel	0-2	Silt/Clay	300-700	144	185
7F05	15-30	4-7	Bedded SS, LS, & SH Sequences	Gravel	0-2	Silt/Clay	100-300	138	181

Ground-Water Pollution Potential of Geauga County

by

Linda Aller and Karen L. Ballou
Geodyssey, Inc.

prepared in cooperation with
Ohio Department of Natural Resources, Division of Water

1 0 1 2 Miles
1 0 1 2 Kilometers

CONTOUR INTERVAL 10 TO 20 FEET

County Line
Township Line
Incorporated City Limit

Pollution Potential Index Range

Higher 200+	
180 - 199	
160 - 179	
to 140 - 159	
120 - 139	
100 - 119	
Lower 80 - 99	

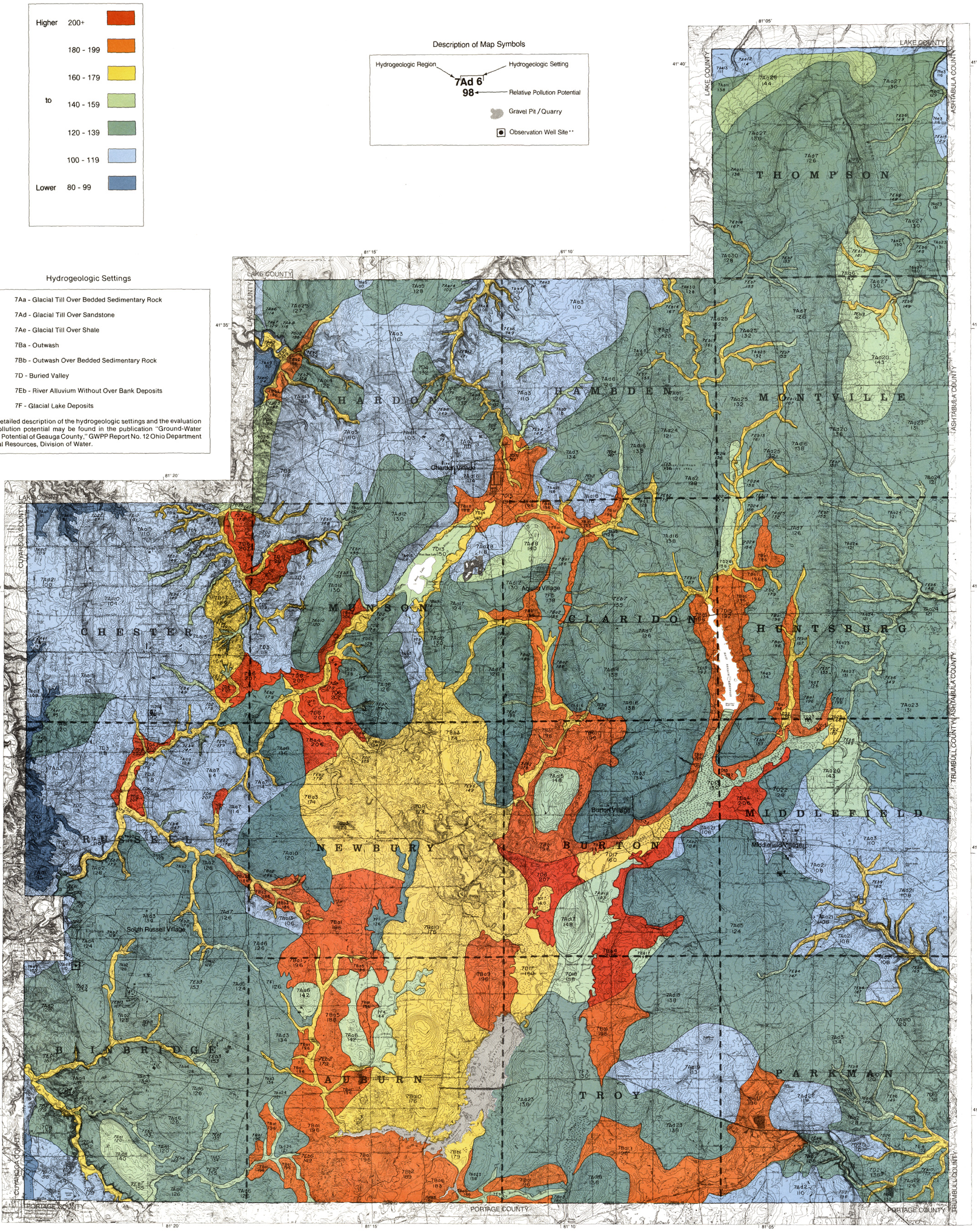
Description of Map Symbols

Hydrogeologic Region — Hydrogeologic Setting
7Ad 6
98 ← Relative Pollution Potential
Gravel Pit / Quarry
Observation Well Site**

Hydrogeologic Settings

- 7Aa - Glacial Till Over Bedded Sedimentary Rock
- 7Ad - Glacial Till Over Sandstone
- 7Ae - Glacial Till Over Shale
- 7Ba - Outwash
- 7Bb - Outwash Over Bedded Sedimentary Rock
- 7D - Buried Valley
- 7Eb - River Alluvium Without Over Bank Deposits
- 7F - Glacial Lake Deposits

A more detailed description of the hydrogeologic settings and the evaluation of the pollution potential may be found in the publication "Ground-Water Pollution Potential of Geauga County," GWPP Report No. 12 Ohio Department of Natural Resources, Division of Water.



The ground-water pollution potential of this county has been mapped using the methodology described in U.S. EPA Publication EPA/600-2-87/035, "DRASTIC: A Standardized System for Evaluating Ground Water Pollution Potential Using Hydrogeologic Settings (Aller et al., 1987)".

Published 1990
Ohio Department of Natural Resources
Division of Water
Ground-Water Resources Section
1939 Fountain Square
Columbus, Ohio 43224

** Observation well sites indicate the location of wells used to collect ground-water level information. These wells are part of the State observation well network. Hydrographs of the water levels recorded in these and other State observation wells can be obtained through ODNR-Division of Water.

Diane Hamilton, Cartographer

Total copies printed: 500
Unit cost: $2.18
Publication date: 7/90

ODNR Ohio Department of Natural Resources
Richard F. Celeste, Governor
Joseph J. Sommer, Director