GROUND WATER POLLUTION POTENTIAL OF HENRY COUNTY, OHIO

BY

HOWARD M. MILLER and JAMES A. HARRELL, University of Toledo

AND

MICHAEL P. ANGLE, ODNR - Division of Water

GROUND WATER POLLUTION POTENTIAL REPORT NO. 45

OHIO DEPARTMENT OF NATURAL RESOURCES

DIVISION OF WATER

WATER RESOURCES SECTION

September, 2002

ABSTRACT

A ground water pollution potential map of Henry County has been prepared 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 incorporate hydrogeologic factors that 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.

Ground water pollution potential analysis in Henry County resulted in a map with symbols and colors, which illustrate areas of varying ground water pollution potential indexes ranging from 67 to 173.

Henry County lies entirely within the Glaciated Central hydrogeologic setting. Limestones and dolomites of the Silurian and Devonian Systems compose the aquifer in the southeastern two thirds of the county. Yields in the uppermost carbonate aquifers range from 5 to 25 gallons per minute (gpm) to 25 to 100 gpm. Yields over 100 gpm are possible from larger diameter wells drilled deeper into the limestone. Shales of the Devonian System comprise the aquifer in the northwestern third of the county. Yields from these rocks are poor, typically yielding less than 5 gpm.

Sand and gravel lenses interbedded in the glacial till locally serve as aquifers in isolated areas. In some areas, the sand and gravel lenses may lie directly on top of the shale or carbonate bedrock and serve as the aquifer or provide additional recharge to the underlying bedrock. Yields for these sand and gravel lenses range from 5 to 25 gpm up to 25 to 100 gpm. Sand and gravel deposits associated with surficial beach and dune deposits may also serve as local shallow aquifers. These aquifers are common in the Oak Openings region in the northeastern corner of the county. Water is obtained from these deposits primarily by shallow, dug wells or drive point wells.

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 Henry 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 area, or to assist in protection, monitoring, and clean-up efforts.

TABLE OF CONTENTS

LIST OF FIGURES

Number Page

LIST OF TABLES

ACKNOWLEDGEMENTS

The preparation of the Henry 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
Map print production and review:	Paul Spahr Michael Hallfrisch
Report production and review:	Michael Hallfrisch Michael Angle Kathy Sprowls
Report editing:	Michael Hallfrisch Michael Angle Kathy Sprowls
Desktop publishing and report design:	David Orr Michael Angle Michael Hallfrisch

INTRODUCTION

The need for protection and management of ground water resources in Ohio has been clearly recognized. About 42 percent of Ohio citizens rely on ground water for drinking and household use from both municipal and private wells. Industry and agriculture also utilize significant quantities of ground water for processing and irrigation. In Ohio, approximately 750,000 rural households depend on private wells; over 2800 of these wells exist in Henry 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, 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 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 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 Henry 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 assisting in county land use planning and resource expenditures related to solid waste disposal. A county may use the map to help identify areas that are suitable for 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.

Pollution potential maps may be applied successfully where non-point source contamination is a concern. Non-point source contamination occurs where land use activities over large areas impact water quality. Maps providing information on relative vulnerability can be used to guide the selection and implementation of appropriate best management practices in different areas. Best management practices should be chosen based upon consideration of the chemical and physical processes that occur from the practice, and the effect these processes may have in areas of moderate to high vulnerability to contamination. For example, the use of agricultural best management practices that limit the infiltration of nitrates, or promote denitrification above the water table, would be beneficial to implement in areas of relatively high vulnerability to contamination.

A pollution potential map can 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 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.

Individuals in the county who are familiar with specific land use and management problems will recognize other beneficial uses of the pollution potential maps. Planning commissions and zoning boards can use these maps to help make informed decisions about the development of areas within their jurisdiction. Developers proposing projects 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. Vulnerability 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 that 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 under the assumption that a contaminant with the mobility of water is introduced at the surface and flushed into the ground water by precipitation. Most important, DRASTIC cannot be applied to areas smaller than 100 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 15 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 Henry County. Inherent within each hydrogeologic setting are the physical characteristics that 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

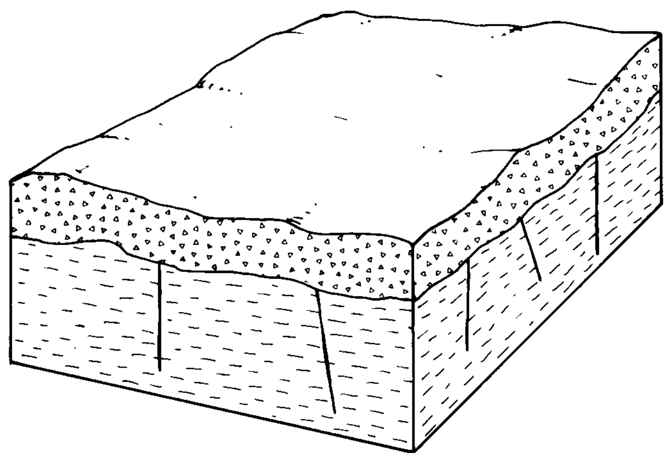
C – Conductivity (Hydraulic) of the Aquifer

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 the aquifer measured in inches per year. Recharge water is available to transport a contaminant from the surface into the aquifer and 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.



7Ae-Glacial Till over Shale

This hydrogeologic setting is limited to the northwestern portion of Henry County. The area is characterized by flat-lying topography and very low relief. The vadose zone is composed of loamy to clayey glacial till and clayey to silty lacustrine deposits at lower elevations. The till and clayey lacustrine sediments may be fractured or jointed, particularly in areas where it is predominantly thin and weathered. Depth to water is variable; shallower depths are more common adjacent to the Maumee River, major tributaries, and the lake plain area. Depths increase towards the northwest panhandle of the county. Soils are generally shrink-swell (aggregated) clays. Areas adjacent to beach ridges have loam or sandy loam soils. The aquifer is usually fractured, massive black Devonian-age shale. In some areas, wells are completed in thin lenses of dirty, shale–rich gravel that directly overly the shale. Yields from the shale are typically less than 5 gpm and range from 5 to 25 gpm for the shaley gravel lenses. Recharge is moderate to low depending upon how thick and clayey the vadose zone and soils are and the depth to water.

Figure 1. Format and description of the hydrogeologic setting - 7Ae Glacial Till over Shale

Soil media refers to the upper six feet of the unsaturated zone that is characterized by significant biological activity. The type of soil media influences 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 slope of an area affects the likelihood that a contaminant will run off 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 has a significant impact on 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 judgment. 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. Where other agricultural practices, such as the application of fertilizers, are a concern, general DRASTIC should be used to evaluate relative vulnerability to contamination. 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 differs significantly. Table 1 lists the weights used for general and pesticide DRASTIC.

TABLE 1. ASSIGNED WEIGHTS FOR DRASTIC FEATURES

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

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	

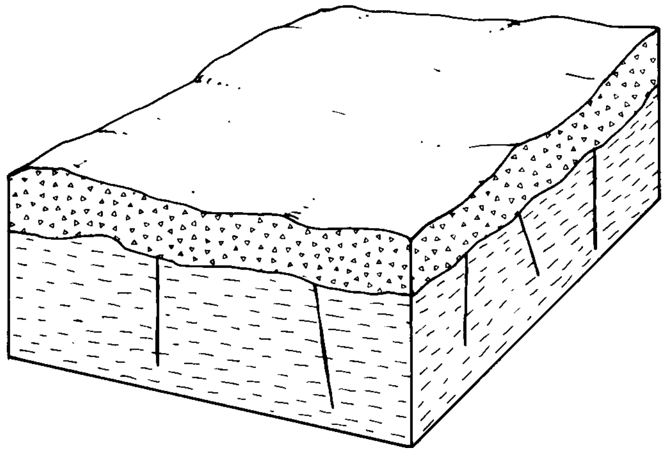
TABLE 8. RANGES AND RATINGS FOR HYDRAULIC CONDUCTIVITY

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 **7Ae1**, identified in mapping Henry 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 **67**. 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 Henry County produces settings with a wide range of vulnerability to ground water contamination. Calculated pollution potential indexes for the six settings identified in the county range from **67** to **173**.

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 Henry 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 Henry County is included with this report.



SETTING 7Ae1		GENERAL		
FEATURE	RANGE	WEIGHT	RATING	NUMBER
Depth to Water	50-75	5	3	15
Net Recharge	2-4	4	3	12
Aquifer Media	Massive Shale	3	2	6
Soil Media	Clay Loam	2	3	6
Topography	0-2%	1	10	10
Impact of Vadose Zone	Silt/Clay	5	3	15
Hydraulic Conductivity	1-100	3	1	3
		DRASTIC	INDEX	67

Figure 2. Description of the hydrogeologic setting - **7Ae1 Glacial Till over Shale**

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:

7Ae1 - defines the hydrogeologic region and setting
67 - defines the relative pollution potential

Here the first number (**7**) refers to the major hydrogeologic region and the upper and lower case letters (**Ae**) refer to a specific hydrogeologic setting. The following number (**1**) references a certain set of DRASTIC parameters that are unique to this setting and are described in the corresponding setting chart. The second number (**67**) 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.

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 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 HENRY COUNTY

Demographics

Henry County occupies approximately 416 square miles in northwestern Ohio (Figure 3). Henry County is bounded to the north by Fulton County, to the northeast by Lucas County, to the east by Wood County, to the south by Putnam County, to the west by Defiance County, and to the northwest by Williams County.

The approximate population of Henry County, based upon 2000 estimates is 29,210 (Department of Development, Ohio County Profiles, 2002). Napoleon is the largest community and the county seat. Agriculture accounts for roughly 92 percent of the land usage in Henry County. Row crops are the primary agricultural land usage. Woodlands, industry, and residential are the other major land uses in the county. More specific information on land usage can be obtained from the Ohio Department of Natural Resources, Division of Real Estate and Land Management (REALM), Resource Analysis Program (formerly OCAP).

Physiography and Topography

Henry County lies within the Lake Plains section of the Central Till Plains Lowland Province (Frost, 1931; Fenneman, 1938, and Bier, 1956). A flat lacustrine plain along with some subdued beach ridges and dunes characterizes Henry County. There is some steeper relief associated with the downcutting of uplands and terraces by the Maumee River, especially in western Henry County.

Climate

The Hydrologic Atlas for Ohio (Harstine, 1991) reports an average annual temperature of approximately 50 degrees Fahrenheit for Henry County. The average temperatures increase slightly towards the southeast. Harstine (1991) shows that precipitation approximately averages 33 to 34 inches per year for the county, with precipitation decreasing towards the southeast and localized higher precipitation near Napoleon. The mean annual precipitation for Napoleon is 34.7 inches per year based upon a thirty-year (1961-1980) period (Owenby and Ezell, 1992). The mean annual temperature at Napoleon for the same thirty-year period is 48.8 degrees Fahrenheit (Owenby and Ezell, 1992).

Figure 3. Location of Henry County

Modern Drainage

Henry County is entirely drained by the Maumee River and its tributaries except for the extreme northwestern panhandle area. This northwestern area, Ridgeville Township, drains westward to the Tiffin River. The southeastern corner of the county has been extensively channelized and artificially drained.

Pre- and Inter-Glacial Drainage Changes

The drainage patterns of Henry County have undergone relatively minor changes as a result of the multiple glaciations. Prior to glaciation, the Napoleon River drained Henry County (Stout et al ,1943, Palombo 1983, and Miller 1997). The course of the modern Maumee River is similar to that of the Napoleon River (Figure 4). Klotz (1981) gives a detailed description of the ancestral Maumee River and its various terrace levels.

Glacial Geology

During the Pleistocene Epoch (2 million to 10,000 years before present (Y.B.P.)) several episodes of ice advance occurred in northwestern Ohio. Older ice advances that predate the most recent (Brunhes) magnetic reversal (about 730,000 Y.B.P.) are now commonly referred to as pre-Illinoian (formerly Kansan). Goldthwait et al, (1961) and Pavey et al, (1999) report that the late Wisconsinan Ice Sheet deposited the surficial till in Henry County. Evidence for the earlier glaciations is lacking or obscured.

Palombo (1983) and Miller (1997) discuss the glacial deposits of Henry County at length. The majority of the glacial deposits fall into three main types: (glacial) till, lacustrine, and beach ridges / dunes. Drift is an older term that collectively refers to the entire sequence glacial deposits. Overall, drift is thickest in the northwestern part of the county and is thinnest in the east-central area (ODNR, Division of Geological Survey, Open File Bedrock Topography and ODNR, Division of Water, Glacial State Aquifer Map)

Till is an unsorted, non-stratified (non-bedded), mixture of sand, gravel, silt, and clay deposited directly by the ice sheet. There are two main types or facies of glacial till. Lodgement till is "plastered-down" or "bulldozed" at the base of an actively moving ice sheet. Lodgement till tends to be relatively dense and compacted and pebbles typically are angular, broken, and have a preferred direction or orientation. "Hardpan" and "boulder-clay" are two common terms used for lodgement till. Ablation or "melt-out" till occurs as the ice sheet melts or stagnates away. Debris bands are laid down or stacked as the ice between the bands melts. Ablation till tends to be less dense, less compacted, and slightly coarser as meltwater commonly washes away some of the fine silt and clay. There is evidence that some of the tills were deposited in a water environment in Henry County. These types of tills would be deposited when a relatively thin ice sheet would alternately float and ground depending on the water level of the lake and thickness of the ice sheet. These types of tills would be deposited when a relatively thin ice sheet would alternately float and ground depending on the water level of the lake and thickness of the ice sheet. Such tills may more closely resemble lacustrine deposits.

Till has relatively low inherent permeability. Permeability in till is in part dependent upon the primary porosity of the till which reflects how fine-textured the particular till is. Vertical permeability in till is controlled largely by factors influencing the secondary porosity such as fractures (joints), worm burrows, root channels, sand seams, etc.

The till has been "wave-planed" or "water-modified" (Forsyth, 1965) at the land surface. Wave activity has eroded away previously existing topographic features. Miller (1997) discusses how the Defiance Moraine was eroded away by the rising lake waters of Lake Maumee. The resulting land surface is flat, gently sloping towards the Maumee River and Lake Erie.

The Lake Plains region of Ohio was flooded immediately upon the melting of glacial ice due to its basin-like topography. River flow into the basin also contributed to the formation of these lakes. Various drainage outlets in Indiana, Michigan, and New York controlled Lake levels over time.

This series of lakes, from ancestral Lake Maumee to modern Lake Erie, had a profound influence on the surficial deposits and geomorphology of the area. Shallow wave activity had a beveling affect on the topography. Clayey to silty lacustrine sediments were deposited into deeper, quieter waters. In shallower areas, beaches and bars were deposited. Some of the beach ridge sand and gravel was deposited by insitu erosion (Anderhalt et al, 1984); the remainder was transported in by local rivers and then re-deposited by wave activity. Coarser sand and gravel was deposited at the shoreline (strandline). Progressively offshore, finer sands, then silts, and then clay were deposited. This accounts for the variable soil types which progress from sands, to sandy loams, to silty loams, to either clays or shrink-swell clays. Lacustrine deposits tend to be laminated or "varved" and contain various proportions of silts and clays. Thin layers of fine sand may reflect storm or flood events. Permeability is preferentially horizontal due to the laminations and water-laid nature of these sediments. The inherent vertical permeability is slow, however, secondary porosity features such as fractures, joints, root channels, etc. help increase the vertical permeability.

The major beach levels in Henry County are listed in Table 9. Figure 4 shows the position of prominent beach ridges associated with Lake Warren and Lake Whittlesey in Henry County. Forsyth (1959 and 1973) gives a detailed discussion of the beach levels and lake history in northwestern Ohio. The beaches form long, narrow low ridges of sand. Coarser sand and gravel form the core of the ridges. Thin sheets of fine sand may lie between the ridges. Wind activity has reworked the beach ridges creating dunes. Dunes cap many of the beach ridges, making it difficult to distinguish the features.

Table 9 LAKE LEVEL SEQUENCE (after Forsyth, 1959 and 1973)

Lake Stage	Age (Years B.P)	Elevation (ft.)	Outlet	Found in Henry County
Erie (modern)	4,000	573	Niagara	no
Algonquin	> 12,000	605	Grand River, Mi or Mohawk River, N.Y.	no
Lundy	>12,200	?	Grand River, Mi or Mohawk River, N.Y.	no
(Elkton)		615	Grand River, Mi or Mohawk River, N.Y.	no
(Dana)		620	Grand River, Mi or Mohawk River, N.Y.	no
(Grassmere)		640	Grand River, Mi	no
Lower Warren		675	Grand River, Mi or Mohawk River, N.Y.	yes
Wayne		655-660	Grand River, Mi or Mohawk River, N.Y.	yes
Upper Warren	<13,000	685-690	Grand River, Mi.	yes
Whittlesey	>13,000	735	Grand River, Mi	yes
Lower Arkona		700	Grand River, Mi	yes
Upper Arkona		710-715	Grand River, Mi	yes
Middle Maumee	14,000	775-780	Wabash River, In	no
Lower Maumee		760	Grand River, Mi	no
Upper Maumee		800	Wabash River, In	no

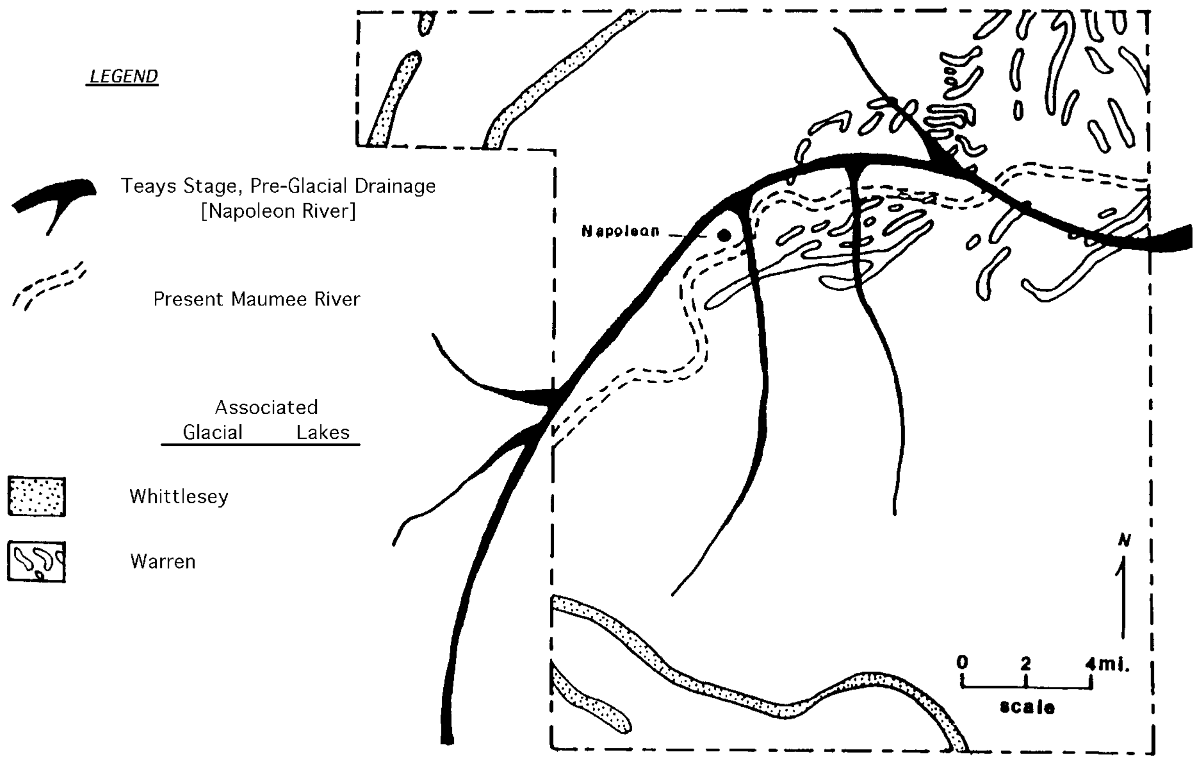


Figure 4. Location of Teays preglacial river valleys and Wisconsinan age beaches and sand bars in Henry County, Ohio (after Miller, 1997 and Palombo, 1983)

Northeastern Henry County contains a relatively wide, thick sequence of beach ridges referred to as the Oak Openings Sands. The name refers to species of oak trees that needed the sandy, drier substrate to grow in. These sands occur at elevations averaging 665-680 ft. that correspond with Lake Warren (Table 9). Two main bodies of sand compose the Oak Openings. The body in Henry County extends through southeastern Fulton County into western Lucas County and into Michigan (Fig. 4). A smaller western body occupies much of central Fulton County (Plymale, 1999 and Plymale et al, 2002). Many explanations for the Oak Openings occur (Burke, 1973, Grube, 1980, Hallfrisch, 1987, and Anderhalt et al, 1984). Most of these explanations suggest that the Oak Openings deposits had a deltaic origin. Opinions differ whether the delta was associated with the ancestral Maumee River or had a more northerly source. Anderhalt et al (1984) also speculated that the delta might have been deposited along the edge of a floating melting ice sheet. The sand in the Oak Openings deposits is laterally extensive. There are some zones where the sand is thicker and where gravel lies directly on top of the underlying till or lacustrine deposits. Well log data in this area also indicates that the sand and gravel lenses interbedded in the glacial till and lacustrine sequences are commonly thicker, coarser, and more continuous then in the surrounding areas. This may indicate that similar type sediments had been deposited in this region before.

Sand and gravel deposits are also associated with the channels and terraces adjacent to the Maumee River (Klotz, 1981). These sand and gravel lenses are interbedded with finer-grained alluvial (floodplain) deposits. Some of these deposits receive recharge directly from the Maumee River. These sediments also serve as avenues of recharge to the underlying bedrock.

Historically, this area was very poorly drained due to the clayey soils and flat topography. During the time of early settlement, most of Henry County was within the Great Black Swamp (Kaatz, 1955). Settlement and transportation were limited to the well-drained beaches and dunes. The remaining areas were not inhabited until the swamp was drained artificially in the 1870’s

Bedrock Geology

Bedrock underlying the surface of Henry County belongs to the Silurian and Devonian Systems. Carbonate (limestone and dolomite) bedrock underlies the southeastern two thirds of Henry County; the northwestern third is underlain by shale bedrock. Table 10 summarizes the bedrock stratigraphy found in Henry County. The ODNR, Division of Geological Survey, has Open-File Reconnaissance Bedrock Geological Maps done on a 1:24,000 USGS Topographic Map Base available for the entire county. The ODNR, Division of Water, has Open File Bedrock State Aquifer mapping available for the county also.

The rock units throughout Henry County are relatively flat-lying, dipping to the northwest roughly 20 feet per mile (Palombo, 1983 and Miler, 1997). The northwest dip is attributed to Henry County lying on the western flank of the northeast trending Findlay Arch. The Findlay Arch is the northeastern extension of the Cincinnati Arch. The Findlay Arch is a deep, subsurface structural feature that has affected the deposition, solution, and hydrogoeolgy of the rock units in the region. The overall bedrock surface tends to be highest toward the southwest and decrease gradually toward Lake Erie.

Deep Silurian carbonates underlie the surface in Henry County. The oldest unit typically encountered by water wells is the Silurian Lockport Group. The Lockport Group rocks were associated with tidal reefs deposited in warm, high-energy shallow seas. Overlying the Lockport Group are rocks of the Silurian Tymochtee and Greenfield Formations, that were also deposited in warm, shallow seas.

Silurian-age limestones and dolomites (collectively carbonates) are the uppermost bedrock formation in the southeastern corner of Henry County. The ODNR, Division of Water, Bedrock State Aquifer Map (2000) refers to these units as the Salina Undifferentiated. These carbonate rocks were deposited in tidal flats associated with warm, shallow seas. These rocks comprise the uppermost bedrock aquifer in this part of the county.

The uppermost carbonate rocks underlying central Henry County are Devonian in age. They belong to three units, from oldest to youngest, the Detroit River Group, the Dundee Limestone, and the Traverse Group. These three units are lithologically and hyrogeologically very similar. They were also deposited in warm shallow seas.

Devonian age Ohio Shale (Palombo, 1983 and Miller, 1997) or Antrim Shale (ODNR, Division of Water, Bedrock State Aquifer Map, 2000) underlies the northwestern third of Henry County. These thick, dark brown to black fissile shales were deposited in deep oceans that had limited circulation of fresher waters and sediments. These shales are rich in organic matter, pyrite, and locally, natural gas.

Table 10. BEDROCK STRATIGRAPHY OF HENRY COUNTY, OHIO

System	Group - Formation	Description
Devonian	Antrim Shale (Ohio Shale)	Black shale, fissile, high-organic, pyretic. Poor source of ground water.
	Traverse Group	Fossiliferous limestone to cherty or sandy dolomite. May include minor shales. Yields range from 0-25 gpm.
	Dundee Limestone	
	Detroit River Group	
Silurian	Undifferentiated Salina Dolomite	Dolomite. Thin to massive bedded. Argillaceous to shaley layers. Vesicular “vuggy” layers, minor solution. Zones of gypsum and anhydrite. Yields vary considerably with fracturing and solution
	Tymochtee and Greenfield	Massive Dolomite, may contain shale partings on laminate bedding, yields vary with fracturing and solution.
	Lockport	Massive Dolomite, fossiliferous – Contains some porous to cavernous zones. Good aquifer

Ground Water Resources

Ground water in Henry County is obtained from both unconsolidated (glacial-alluvial) and consolidated (bedrock) aquifers. Glacial aquifers are primarily associated with thin lenses of sand and gravel interbedded with till and lacustrine material or with the surficial beach ridge deposits. The carbonate aquifer is an important regional aquifer for most of northwestern Ohio.

Yields exceeding 100 gpm (ODNR, Div. Of Water, Open File, Bedrock State Aquifer Map, 2000, ODNR, Div. Of Water, 1970, Palombo, 1983, Schmidt, 1982, and Miller, 1997) are available from deep larger diameter wells drilled into the Salina Undifferentiated Group. The Lockport extends across the southeastern half of the county at depth. Yields for the Silurian Tymochtee-Greenfield Formations vary from 5 to 25 gpm up to 25 to 100 gpm from these relatively deep aquifers (ODNR, Div. of Water, Open File, Bedrock State Aquifer Map, 2000). Along the eastern edge of the county, The Salina Undifferentiated Group produces yields of 25 to 100 gpm to greater than 100gpm (ODNR, Div. of Water, Open File, Bedrock State Aquifer Map, 2000 and Schmidt, 1982)). The Salina Undifferentiated is the uppermost aquifer in the southeastern corner, but underlies the Traverse Group in northeastern Henry County. Yields from the Detroit River Group, Dundee Limestone, and the Traverse Group are moderate, ranging from 5 to 25 gpm up to 25 to 100 gpm (ODNR, Div. Of Water, Open File, Bedrock State Aquifer Map, 2000, ODNR, Div. Of Water, 1970, Palombo, 1983, Schmidt, 1982, and Miller, 1997).

The trend of increasing yields in deeper wells drilled into the carbonates is a generalization. The amount of fracturing, solution, and vuggy (porous) zones has great local importance. The ODNR, Division of Water (1970) gives an extensive discussion on solution features and yields of the carbonates and how these are affected by their position relative to the Findlay Arch. Deeper wells are also more likely to contain highly mineralized water and have objectionable water quality. Carbonate aquifers that underlie the thick sequence of shales in northwestern Henry County are not considered to be potable ODNR, Div. Of Water, Open File, Bedrock State Aquifer Map, ODNR. Water underlying the shale tends to be very high in sulfur, hydrogen sulfide, and iron.

The Antrim Shale (or Ohio Shale) in northwestern Henry County is a poor source of ground water. Yields are typically under 5 gpm (Palombo, 1983 and Schmidt, 1982). Typically, the uppermost 10 to 15 feet of the shale is weathered and broken and provides the most water. Wells drilled deeper into the shale provide increased well storage, but typically little additional water. The water quality becomes more objectionable with depth.

Yields from sand and gravel lenses interbedded with the fine-grained till and lacustrine deposits averages 5 to 25 gpm (ODNR, Div. of Water, Glacial State Aquifer Map, 2000, Palombo, 1983, and Miller, 1997). The sand and gravel may also directly overlie the bedrock (Palombo, 1983 and Miller, 1997) and yield 5 to 25 gpm. The sand and gravel directly underlying the till boundary may undergo cementation due to the chemical precipitation of iron and calcite. Such localized zones are very hard and are referred to by well drillers as hardpan. (Note- Hardpan may also refer to dense till in some logs). Yields up to 25 to 100 gpm are associated with the terraces and channels adjacent to the Maumee River. The drillers may penetrate the bedrock directly below the sand and gravel. In such cases the bedrock acts as a –screenÓ to help filter fines out of the gravel. Sand and gravel lenses interbedded with fine-grained alluvial (floodplain) deposits have yields ranging from 5 to 25 gpm up to 25 to 100 gpm. These yields depend upon how well the underlying coarse deposits are interconnected with the Maumee River and tributaries. It is important to note that sand and gravel wells are much more commonly utilized in northern Henry County as the underlying shale is a much poorer aquifer than the carbonates to the south.

The sand and gravel beach ridges are utilized as local aquifers in northern Henry County. The Oak Openings in northeastern Henry County represent some of the thickest, most widespread beach deposits in the state (Palombo, 1983, Miller, 1997, and ODNR, Div. of Water, Open File, Glacial State Aquifer Map, 2000). Beach ridges and overlying dunes are primarily composed of relatively fine-grained sand; however the basal section of some of these ridges contains coarse gravel and sand. The fine sands tend to store a large amount of water, but have moderately slow permeability. The water tends to perch or collect in the beach deposits that overlie the dense, low permeability lacustrine deposits or tills. Permeability and yields are moderate in the fine sand zones and average 5 to 25 gpm. Yields may increase in the coarser gravel-bearing zones.

Conventional drilled wells are not especially affective due to the shallow nature of these deposits. Large diameter (usually over 30 inches) dug wells are commonly used. These may yield up to 50 gpm. Some of these dug wells may also have short, drilled sections to house the pump and increase storage. Trenches and artificial ponds may be excavated into shallow, saturated deposits to aid in extracting water. Shallow well points also have been utilized in many areas. These tend to have yields of less than 5 gpm up to 5 to 25 gpm.

REFERENCES

Aller, L., T. Bennett, J.H. Lehr, R.J. Petty and G. Hackett, 1987. DRASTIC: A Standardized System for Evaluating Ground Water Pollution Potential Using Hydrogeologic Settings. U.S. Environmental Protection Agency EPA/600/2-87-035, 622 pp.

Anderhalt, R., C.F. Kahle, and D. Sturgis, 1984. The Sedimentology of a Pleistocene Glaciolacustrine Delta near Toledo, Ohio. Society of Economic Paleontologists and Mineralogists, Great Lakes Section, Fourteenth Annual Field Conference, Field Guidebook, p. 59-90.

Angle, M.P. and B. Ziss, 2002. Ground Water Pollution Potential of Williams County, Ohio. Ohio Department of Natural Resources, Division of Water, GWPP Report no. 60.

Bier, J.A., 1956. Landforms of Ohio. Ohio Department of Natural Resources, Division of Geological Survey, map.

Burke, M.R., 1973. Stratigraphic analysis of the Oak Openings Sand, Lucas County, Ohio. Unpublished M.S. Thesis, The University of Toledo, Toledo, Ohio, 108 pp.

Driscoll, F.G., 1986. Groundwater and wells. Johnson Filtration Systems , St. Paul, Mn, 1089 pp.

Dumouchelle, D.H. and M.C. Schiefer, 2002. Use of streamflow records and basin characteristics to estimate ground-water recharge rates in Ohio. Ohio Department of Natural Resources, Division of Water, Bulletin 46, 45 pp.

Eyles, N. and J.A. Westgate, 1987. Restricted regional extent of the Laurentide Ice Sheet in the Great Lakes Basin during early Wisconsinan Glaciation. Geology, v. 15, p. 537-540.

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

Fetter, C.W., 1980. Applied hydrogeology. Charles E. Merrill Publishing Co., Columbus, Ohio, 488 pp.

Flesher, E.C., K.L. Stone, L.K. Young, and D.R. Urban, 1974. Soil Survey of Henry County, Ohio. U.S. Department of Agriculture, Natural Resources Conservation Service, 128 pp.

Forsyth, J.L., 1959. The beach ridges of northern Ohio. Ohio Department of Natural Resources, Division of Geological Survey, Information Circular, No. 25.

Forsyth, J. L., 1965. Water-modified till of the lake plain of northwestern Ohio. Ohio Journal of Science, v. 65, no. 2, p. 96

Forsyth, J.L., 1973. Late-glacial and postglacial history of western Lake Erie. Compass of Sigma Gamma Epsilon, v. 51, no. 1, p. 16-26.

Freeze, R.A. and J.A. Cherry, 1979. Ground water. Prentice-Hall, Englewood Cliffs, N.J., 604 pp.

Frost, R.B., 1931. Physiographic map of Ohio. Oberlin College, The Geographical Press, Columbia Univ., N.Y., N.Y., map with text.

Goldthwait, R.P., G.W. White, and J.L. Forsyth, 1961. Glacial Map of Ohio. U. S. Department of Interior, Geological Suvey, Miscellaneous Map, I-316, map with text.

Grube, M.H., 1980. The origin and development of the southern portion of the Oak Openings sand belt, Lucas County, Ohio. Unpublished M.S. Thesis, Bowling Green State University, Bowling Green, Ohio, 144 pp.

Hallfrisch, M.P., 1987. Unconfined sand aquifer characteristics of a forested and a nonforested area, Maumee State Forest, Fulton County, Ohio. Unpublished M.S. Thesis, University of Toledo, Toledo, Ohio, 146 p.

Hallfrisch, M.P., 2002. Ground Water Pollution Potential of Lucas County, Ohio. Ohio Department of Natural Resources, Division of Water, GWPP Report no. 33.

Harstine, L.J., 1991. Hydrologic atlas for Ohio. Ohio Department of Natural Resources, Division of Water, Water Inventory Report, No. 28, 13 pp.

Kaatz, M.K., 1955. The Black Swamp: A Study in Historical Geography. Annals of the Association of American Geographers, Vol. 55, No.1, p. 1-35.

Klotz, J.A., 1981. Nature and origin of the Maumee River Terraces, Northwestern Ohio. Unpublished M.S. Thesis, Bowling Green State University, 51 pp.

Miller , H.M.., 1997. Evaluation of Ground-Water Pollution Potential of Henry County, Ohio, using the DRASTIC Mapping System. Unpublished M.S. Thesis, University of Toledo, Toledo, Ohio, 408 pp.

Miller, H.M. and M.P. Angle, 2002. Ground Water Pollution Potential of Henry County, Ohio. Ohio Department of Natural Resources, Division of Water, GWPP Report no. 45.

Ohio Department of Natural Resources, Division of Geological Survey, Open File, Reconnaissance Bedrock Geology Maps. Available on a U.S.G.S. 7-1/2 minute Quadrangle basis.

Ohio Department of Natural Resources, Division of Geological Survey, Open File, Bedrock Topography Maps. Available on a U.S.G.S. 7-1/2 minute Quadrangle basis.

Ohio Department of Natural Resources, Division of Water, 1970. Ground water for planning in northwest Ohio: A study of the carbonate rock aquifers. Ohio Water Plan Inventory Report no. 22, 63 pp.

Ohio Department of Natural Resources, Division of Water, Open File Bedrock State Aquifer Maps. Available on a U.S.G.S. 7-1/2 minute Quadrangle basis.

Ohio Department of Natural Resources, Division of Water, Open File Glacial State Aquifer Maps. Available on a U.S.G.S. 7-1/2 minute Quadrangle basis.

The Ohio Drilling Company, 1971. Ground Water Potential of Northeast Ohio. Consultant's report prepared for the Ohio Department of Natural Resources, Division of Water, 361 pp.

Owenby, J.R. and D.S. Ezell, 1992. Monthly station normals of temperature, precipitation, and heating and cooling degree-days, 1961-1990. Climatography of the United States No. 81, OHIO. U.S. Department of the Interior, Project A-051-OHIO,

U.S. Department of Commerce, National Oceanic and Atmospheric Administration, 30 pp.

Palombo, K.M., 1983. Ground-Water Resources of Henry County, Ohio. Unpublished M.S. Thesis, University of Toledo, Toledo, Ohio, 164 pp.

Pavey, R.R., R.P. Goldthwait, C. S. Brockman, D.N. Hull, E.M. Swinford, and R.G. Van Horn, 1999. Quaternary Geology of Ohio. Ohio Department of Natural Resources, Division of Geological Survey, Map No. 2, map with text.

Plymale, C.L., 1999. Evaluation of the Ground-Water Pollution Potential of Fulton County, Ohio, using the DRASTIC Mapping System. Unpublished M.S. Thesis, University of Toledo, Toledo, Ohio, 480 pp.

Plymale, C. L. and M.P. Angle, 2002. Ground Water Pollution Potential of Fulton County, Ohio. Ohio Department of Natural Resources, Division of Water, GWPP Report no. 44.

Pettyjohn, W.A. and R. Henning, 1979. Preliminary estimate of ground water recharge rates, related streamflow and water quality in Ohio. U.S. Department of the Interior, Project A-051-OHIO, Project Completion Report No. 552, Water Resources Center, The Ohio State University, Columbus, Ohio, 323 pp.

Schmidt, J.J., 1982. Ground Water Resources of Henry County. Ohio Department of Natural Resources, Division of Water, map with text.

Smith, K.C., 1994. Ground Water Pollution Potential of Hancock County, Ohio. Ohio Department of Natural Resources, Division of Water, GWPP Report no. 14, 78 pp.

Smith, K.C. and T.P. Sabol, 1994. Ground Water Pollution Potential of Wood County, Ohio. Ohio Department of Natural Resources, Division of Water, GWPP Report no. 21, 67 pp.

UNPUBLISHED DATA

Ohio Department of Development. Office of Strategic Research, Countywide profiles, 1999.

Ohio Department of Natural Resources, Division of Water. Well log and drilling reports for Henry County

APPENDIX A

DESCRIPTION OF THE LOGIC IN FACTOR SELECTION

Depth to Water

This factor was primarily evaluated using information from water well log records on file at the Ohio Department of Natural Resources (ODNR), Division of Water, Water Resources Section (WRS). Depth to water data was taken directly from the thesis of Miller (1997) for most areas. Approximately 2800 water well log records are on file for Henry County. Data from roughly 1,200 located water well log records were analyzed and plotted on U.S.G.S. 7-1/2 minute topographic maps during the course of the project. Static water levels and information as to the depths water was encountered at were taken from these records. The Ground Water Resources of Henry County (Schmidt, 1982) and the thesis of Palombo (1983) provided generalized depth to water information throughout the county. Depth to water trends mapped in adjoining Fulton County (Plymale, 1999 and Plymale et al., 2002), Lucas County (Hallfrisch, 2002), Wood County (Smith and Sabol, 1994), Williams County (Angle and Ziss, 2002), and Hancock County (Smith, 1994) were used as a guideline. Topographic and geomorphic trends were utilized in areas where other sources of data were lacking.

Depths to water of 0 to 5 (10) were used for some limited floodplain areas adjacent to the Maumee River. Depths of 5 to 15 feet (9) were selected for Floodplains and low terraces adjacent to the Maumee River and for the Oak Opening beach ridges in Washington and Liberty Townships. Depths of 15 to 30 feet (7) were mapped adjacent to the Maumee River and most tributaries. Depths of 15 to 30 feet (7) were used for most of the 7F-Glacial Lake Deposits and 7H-Beaches, Beach Ridges and Sand Dunes settings and for the 7Ac-Till over Limestone setting in the eastern half of the county. Depths of 30 to 50 feet (5) were utilized for the 7Ac-Till over Limestone in the western half of the county and in the 7Ae-Till over Shale hydrogeolgic setting in the northwestern corner of the county. Depths to water of 50 to 75 feet (3) were utilized for higher elevation areas in the northwestern panhandle of the county. The till overlying the shale thickens in this portion of the 7Ae-Till over Shale hydrogeologic setting.

Net Recharge

This factor was evaluated using many criteria, including depth to water, topography, soil type, surface drainage, vadose zone material, aquifer type, and annual precipitation. General estimates of recharge provided by Pettyjohn and Henning (1979) and Dumouchelle and Schiefer (2002) proved to be helpful. Recharge is the precipitation that reaches the aquifer after evapotranspiration and run-off. Estimates for recharge were derived principally from the thesis of Miller (1997). Recharge ratings from Fulton County (Plymale, 1999 and Plymale et al, 2002), Lucas County (Hallfrisch, 2002), Wood County (Smith and Sabol, 1994), Williams County (Angle and Ziss, 2002), and Hancock County (Smith, 1994) were used as a guideline.

Recharge values of greater than 10 inches per year (9) were evaluated for the shallow beach ridge aquifers associated with the Oak Openings in northeastern Henry County. Recharge values of 7 to 10 inches per year (8) were assigned to coarser-grained deposits in floodplains and terraces adjacent to the Maumee River and for some beach ridges in Harrison Township. Values of 4 to 7 inches per year (6) were used for areas with moderate recharge. These areas include most of the tributary streams in the county as well as areas with moderate depths to water and moderately permeable soils. Values of 2 to 4 inches per year (3) were utilized for most of the 7Ae-Glacial Till over Shale and 7Ac-Glacial Till over Limestone hydrogeologic settings. These areas have clayey, low permeability soils and vadose materials and moderate to great depths to water.

Aquifer Media

Information on evaluating aquifer media was obtained from the maps and reports of the ODNR, Div. of Water, (1970), Schmidt (1982), and Palombo (1983). Open File Bedrock Reconnaissance Maps and Open File Bedrock Topography Maps, based upon U.S.G.S. 7-1/2 minute Topographic Maps from the ODNR, Division of Geological Survey proved helpful. Most ratings were taken directly from the thesis of Miller (1997). Aquifer ratings from neighboring Fulton County (Plymale et al, 2002), Lucas County (Hallfrisch, 2002), Wood County (Smith and Sabol, 1994), Williams County (Angle and Ziss, 2002), and Hancock County (Smith, 1994) were used as a guideline. The ODNR, Division of Water, Glacial State Aquifer Map and Bedrock State Aquifer Map were an important source of aquifer data. Water well log records on file at the ODNR, Division of Water, were the primary source of aquifer information.

All of the bedrock and most of the interbedded lenses of sand and gravel are semi-confined or leaky; however for the purposes of DRASTIC, they have been evaluated as being unconfined (Miller, 1997 and Aller et al, 1987). Massive limestone was evaluated as the aquifer in the 7Ac-Glacial Till over Limestone and in adjacent settings with carbonate aquifers. A rating of (8) was applied to the higher-yielding Silurian limestones that form the uppermost aquifer in southeastern Henry

County. These rocks tend to have more solution features and higher secondary porosity. A rating of (7) was utilized for the other limestone aquifers.

An aquifer rating of (2) was selected for the shale aquifers due to overall low permeability and yields of these rocks.

For sand and gravel aquifers a rating of (7) was given to the clean sands of the Oak Openings beach ridges and for some of the beach ridges south of the Maumee River. An aquifer rating of (6) was applied to sand and gravel lenses underlying some of the floodplains, terraces, and former channels adjacent to the Maumee River. An aquifer rating of (5) was used for the sand and gravel lenses interbedded with finer-grained till and lacustrine deposits. These deposits with a (5) rating tend to be thinner, more discontinuous, and more poorly sorted and are commonly south of the Maumee River.

Soils

Soils were mapped using the data obtained from the Soil Survey of Henry County (Flesher et al, 1974). Each soil type was evaluated and given a rating for soil media. Evaluations were based upon the texture, permeability, and shrink-swell potential for each soil material. Special emphasis is placed upon determining the most restrictive layer. The soils of Henry County showed a high degree of variability. This is a reflection of the parent material. Table 11 is a list of the soils, parent materials, setting, and corresponding DRASTIC values for Henry County.

Soils were considered to be gravel (10) for a limited number of terraces along the Maumee River just east of Napoleon. Other gravel (10) soils were evaluated an area of outwash and kettles along the Fulton County boundary. Sand (9) was selected for the soil type for beach ridges and dunes with thicker accumulations of fine-grained sand. These soils are very common in the Oak Openings area. Shrink-swell (aggregated) clay (7) was selected for most of the high-clay lacustrine soils and the high clay wave-planed glacial till. They behave similar to clay loams at these times. During dry summer months, these soils desiccate and shrink, creating large cracks or fractures that serve as effective avenues for contaminants to migrate downward into the water table. Sandy loams (6) were selected for soils overlying beach ridges and some stream terraces. Loam soils (5) were designated for medium-textured soils on floodplain terraces. Loam soils (5) were also used for medium-textured, thin silty deltaic deposits. Silt loam (4) soils were evaluated for silty alluvial deposits particularly in the headwaters of tributaries. Clay loam (3) soils were evaluated for areas with moderately clay-rich lacustrine sediments.

Table 11. DRASTIC RATINGS FOR LUCAS COUNTY SOILS

Soil Name	Parent Material or Setting	DRASTIC Rating	Soil Media
Adrian	lacustrine – depression	2	muck
Arkport	dune, beach	6	sandy loam
Cohoctah	alluvium	6	sandy loam
Colwood	beach, delta	5	loam
Del Rey	lacustrine	7	shrink/swell clay
Digby	deltaic	5	loam
Fulton	lacustrine	7	shrink/swell clay
Galen	beach, dune	9	sand
Genesee	alluvium	5	loam
Gilford	beach, delta	6	sandy loam
Granby	beach,dune	6	sandy loam
Haskins	beach over till	3	clay loam
Hoytville	wave-modified till	7	shrink swell clay
Kibbie	delta	5	loam
Latty	lacustrine	7	shrink/swell clay
Lenowee	lacustrine	7	shrink/swell clay
Lucas	lacustrine	7	shrink/swell clay
Medway	alluvium	4	silt loam
Mermill	wave-modified till	7	shrink/swell clay
Millgrove	beach	6	sandy loam
Nappanee	wave-modified till	7	shrink/swell clay
Oakville	beach, dune	9	sand
Oshtemo	beach, deltaic	6	sandy loam
Ottokee	beach, dune	9	sand
Paulding	lacustrine	7	shrink/swell clay
Rawson	beach over lacustrine	7	shrink/swell clay
Rimer	beach over till	7	shrink/swell clay
Roselms	lacustrine	7	shrink/swell clay
Ross	alluvium	4	silt loam
St. Clair	lacustrine	7	shrink/swell clay
Seward	beach over till	7	shrink/swell clay
Shinrock	beaches, delta	6	sandy loam
Shoals	alluvium	5	loam
Sloan	alluvium	5	silt loam
Spinks	beach, dune	9	sand
Tedrow	beach, dune	9	sand
Toledo	lacustrine	7	shrink/swell clay
Tuscola	deltaic	4	silt loam

TABLE 10 (continued). DRASTIC RATINGS FOR LUCAS COUNTY SOILS

Soil Name	Parent Material or Setting	DRASTIC Rating	Soil Media
Vaughnsville	deltaic	5	loam
Wabasha	fine alluvium	7	shrink/swell clay
Warners	deprission	2	muck
Wauseon	beach, dune	6	sandy loam

Topography

Topography, or percent slope, was evaluated using U.S.G.S. 7-1/2 minute quadrangle maps and the Soil Survey of Henry County (Flesher et al, 1974). Slopes of 0 to 2 percent (10) and 2 to 6 percent (9) were selected for almost all of the settings for Henry County due to the overall flat-lying to gently rolling topography and low relief. These slopes were used for most of the lake plains, wave-planed tills and floodplains. Slopes of 6 to 12 percent (5) were used for moderately steep margins along terraces and a few steeper beach ridges. Slopes of 12 to 18 percent (3) and greater than 18 percent (1) were selected for a limited number of areas where the Maumee River has steeply downcut the surrounding bluffs. Special emphasis is placed upon determining the most restrictive layer.

Impact of the Vadose Zone Media

Information on evaluating vadose zone media was obtained from the maps and reports of the ODNR, Div. of Water, (1970), Schmidt (1982), Palombo (1983), Open File Bedrock Reconnaissance Maps and Open File Bedrock Topography Maps, based upon U.S.G.S. 7-1/2 minute Topographic Maps from the ODNR, Division of Geological Survey proved helpful. Most ratings were taken directly from the thesis of Miller (1997). Fulton County (Plymale et al, 2002), Lucas County (Hallfrisch, 2002), Wood County (Smith and Sabol, 1994), Williams County (Angle and Ziss, 2002), and Hancock County (Smith, 1994) were used as a guideline. The ODNR, Division of Water, Glacial State Aquifer Map and Bedrock State Aquifer Map were an important source of aquifer data. The Soil Survey of Henry County (Flesher et al, 1974) provided valuable information on parent materials. The State Glacial Map (Goldthwait et al, 1961 and Pavey et al, 1999) was useful in delineating vadose zone media. Water well log records on file at the ODNR, Division of Water, were the primary source of aquifer information.

The vadose zone media is a critical component of the overall DRASTIC rating in Henry County (Miller, 1997). The rating varies with the restrictive properties of the various glacial materials. The higher the proportion of silt and clay and the greater the compaction (density) of the sediments, the lower the permeability and the lower the vadose zone media are rated.

Sand and Gravel with Silt and Clay with a rating of (7) was selected as the vadose zone material for the coarser beach ridge deposits, particularly in the Oak Openings. Sand and Gravel with Silt and Clay with a rating of (6) was used for somewhat finer-grained beach ridges and sand dunes south of the Maumee River in Harrison Township. Sand and Gravel with Silt and Clay with a rating of (5) was applied to finer beach deposits, silty deltaic and lacustrine sediments, and most of the floodplains and terraces.

Silt and Clay with a rating of (4) was used for the vadose zone media for most areas with glacial till and for some of the areas with thicker clayey lacustrine sediments. Silt and Clay with a rating of (3) was used for areas with thicker sequences of glacial till. Miller (1997) suggested that the till, in thicker accumulations, is less likely to be weathered and fractured and tends to be more compacted (dense). These thicker sequences of till are found in the northwestern and southwestern corners of the county.

Hydraulic Conductivity

Information on evaluating the hydraulic conductivity was obtained from the maps and reports of the ODNR, Div. of Water, (1970), Schmidt (1982), Palombo (1983), Open File Bedrock Reconnaissance Maps and Open File Bedrock Topography Maps, based upon U.S.G.S. 7-1/2 minute Topographic Maps from the ODNR, Division of Geological Survey proved helpful. Most ratings were taken directly from the thesis of Miller (1997). Fulton County (Plymale et al, 2002), Lucas County (Hallfrisch, 2002), Wood County (Smith and Sabol, 1994), Williams County (Angle and Ziss, 2002), and Hancock County (Smith, 1994) were used as a guideline. The ODNR, Division of Water, Glacial State Aquifer Map and Bedrock State Aquifer Map were an important source of aquifer data. Water well log records on file at the ODNR, Division of Water, were the primary source of aquifer information. Textbook tables (Freeze and Cherry, 1979, Fetter, 1980, and Driscoll, 1986) were useful in obtaining estimated values for hydraulic conductivity in a variety of sediments.

Values for hydraulic conductivity correspond to aquifer ratings; i.e., the more highly rated aquifers have higher values for hydraulic conductivity. All of the glacial aquifers have been given a hydraulic conductivity rating of 100-300 gallons per day per square foot (gpd/ft2). This rating reflects the overall fine-grained nature of these sands and the presence of fines.

Higher-yielding Silurian limestone aquifers with an aquifer media rating of (8) were assigned a hydraulic conductivity rating of 300-700 gpd/ft2 (4). These rocks are rated as the uppermost aquifer in the southeastern corner of the county. All of the other limestone aquifers were given a hydraulic conductivity of 100-300 (2). All of the shale aquifers in northwestern Henry County were assigned a hydraulic conductivity rating of 1-100 gpd/ft2 (1).

APPENDIX B

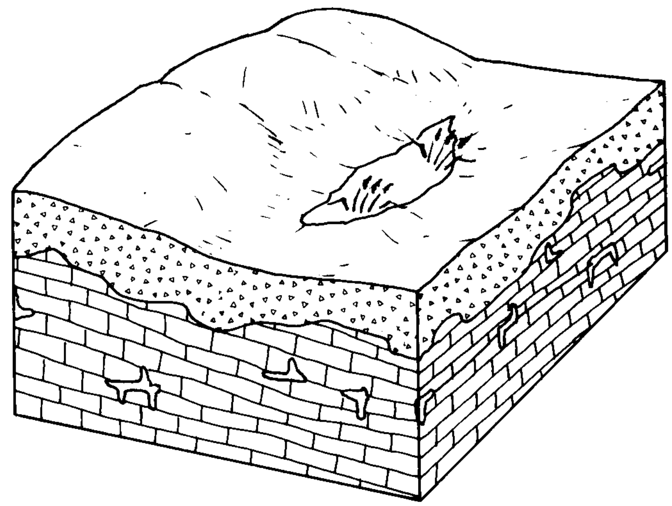
DESCRIPTION OF HYDROGEOLOGIC SETTINGS AND CHARTS

Ground water pollution potential mapping in Henry County resulted in the identification of ten 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 12. Computed pollution potential indexes for Lucas County range from 67 to 173.

Table 12. Hydrogeologic Settings Mapped in Henry County, Ohio.

Hydrogeologic Settings	Range of GWPP Indexes	Number of Index Calculations
7Ac - Glacial Till over Solution Limestone	93 - 136	24
7Ae - Glacial till over Shale	67 - 129	30
7Af - Sand and Gravel Interbedded in Glacial Till	129	1
7Ea - Rver alluvium with Overbank Deposits	95 - 151	36
7Eb - River Alluvium without Overbank Deposits	148	1
7Ec - Alluvium over Sedimentary Rock	134	1
7Ed - Alluvium over Glacial Till	152	1
7F - Glacial Lake Plains Deposits	86 - 143	51
7H - Beaches, Beach Ridge, and Sand Dunes	94 - 173	32
7I - Marshes and Swamps	173	1

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.

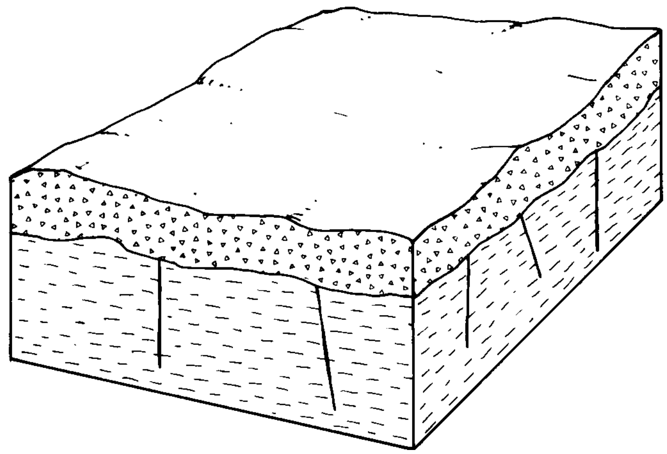


7Ac-Glacial Till over Solution Limestone

This hydrogeologic setting is widespread across the southern half of the Henry County. The area is characterized by flat-lying topography and very low relief. The vadose zone consists primarily of silty to clayey glacial till and lacustrine sediments. The till and clayey lacustrine sediments may be fractured or jointed, particularly in areas where it is predominantly thin and weathered. In areas adjacent to beach ridges, the vadose may contain somewhat loamier materials. The aquifer is composed of fractured Silurian and/or Devonian limestones and dolomites. These carbonate rocks may contain significant solution features. Depth to water is typically shallow to moderate; overall, the depth to water increases toward the southwest corner of the county. Soils are typically shrink-swell (aggregated) clays or clay loams derived from till or lacustrine deposits. Soils overlying the thin, marginal beach deposits are loams to sandy loams. Ground water yields average 25-100 gpm for the Silurian Lockport and Salina Groups and 5 to 25 gpm for the Devonian carbonate units. Recharge is low to moderate depending upon how thick and clayey the vadose zone media and soils are limited due to the steep slopes, deep aquifers, and layers of impermeable bedrock.

GWPP index values for the hydrogeologic setting of Glacial Till over Solution Limestone range from 93 to 136 with the total number of GWPP index calculations equaling 24.

Setting	Depth to water (ft.)	Recharge in./yr.	Aquifer Media	Soil Media	Topography % Slope	Vadose Zone Media	Hydro. Cond.	Rating
7Ac01	50-75	2-4	Massive Limestone	S/S Clay	0-2	Silt/Clay	100-300	93
7Ac02	30-50	2-4	Massive Limestone	Clay Loam	0-2	Silt/Clay	100-300	95
7Ac03	50-75	2-4	Massive Limestone	S/S Clay	0-2	Silt/Clay	100-300	98
7Ac04	50-75	2-4	Massive Limestone	S/S Clay	0-2	Silt/Clay	300-700	102
7Ac05	15-30	4-7	Massive Limestone	Loam	0-2	Silt/Clay	100-300	126
7Ac06	15-30	2-4	Massive Limestone	Clay Loam	12-18	Silt/Clay	100-300	103
7Ac07	30-50	2-4	Massive Limestone	S/S Clay	0-2	Silt/Clay	100-300	103
7Ac08	30-50	2-4	Massive Limestone	Loam	0-2	Silt/Clay	100-300	104
7Ac09	15-30	4-7	Massive Limestone	S/S Clay	0-2	Snd. & Gr.	100-300	135
7Ac10	30-50	2-4	Massive Limestone	Sandy Loam	0-2	Silt/Clay	100-300	106
7Ac11	30-50	2-4	Massive Limestone	S/S Clay	0-2	Silt/Clay	100-300	108
7Ac12	15-30	4-7	Massive Limestone	S/S Clay	0-2	Silt/Clay	100-300	130
7Ac13	30-50	2-4	Massive Limestone	S/S Clay	0-2	Silt/Clay	300-700	112
7Ac14	5-15	2-4	Massive Limestone	S/S Clay	0-2	Silt/Clay	100-300	113
7Ac15	15-30	2-4	Massive Limestone	S/S Clay	0-2	Silt/Clay	300-700	127
7Ac16	5-15	4-7	Massive Limestone	Loam	0-2	Silt/Clay	100-300	136
7Ac17	15-30	2-4	Massive Limestone	S/S Clay	0-2	Silt/Clay	100-300	113
7Ac18	30-50	4-7	Massive Limestone	S/S Clay	0-2	Snd. & Gr.	100-300	125
7Ac19	15-30	2-4	Massive Limestone	Loam	0-2	Silt/Clay	100-300	114
7Ac20	30-50	2-4	Massive Limestone	S/S Clay	0-2	Silt/Clay	300-700	117
7Ac21	15-30	2-4	Massive Limestone	S/S Clay	0-2	Silt/Clay	100-300	118
7Ac22	15-30	2-4	Massive Limestone	S/S Clay	0-2	Silt/Clay	300-700	122
7Ac23	30-50	4-7	Massive Limestone	Sandy Loam	0-2	Snd. & Gr.	100-300	123
7Ac24	15-30	2-4	Massive Limestone	S/S Clay	0-2	Snd. & Gr.	100-300	123



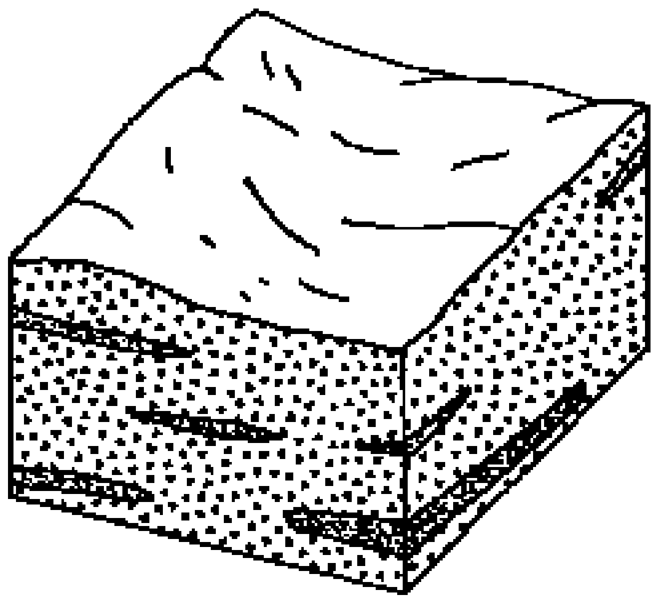
7Ae-Glacial Till over Shale

This hydrogeologic setting is limited to the northwestern portion of Henry County. The area is characterized by flat-lying topography and very low relief. The vadose zone is composed of loamy to clayey glacial till and clayey to silty lacustrine deposits at lower elevations. The till and clayey lacustrine sediments may be fractured or jointed, particularly in areas where it is predominantly thin and weathered. Depth to water is variable; shallower depths are more common adjacent to the Maumee River, major tributaries, and the lake plain area. Depths increase towards the northwest panhandle of the county. Soils are generally shrink-swell (aggregated) clays. Areas adjacent to beach ridges have loam or sandy loam soils. The aquifer is usually fractured, massive black Devonian-age shale. In some areas, wells are completed in thin lenses of dirty, shale–rich gravel that directly overly the shale. Yields from the shale are typically less than 5 gpm and range from 5 to 25 gpm for the shaley gravel lenses. Recharge is moderate to low depending upon how thick and clayey the vadose zone and soils are and the depth to water.

GWPP index values for the hydrogeologic setting of Glacial Till over Shale range from 67 to 129 with the total number of GWPP index calculations equaling 30.

Hydrogeologic Setting Values for: 7Ae-Glacial Till over Shale

Setting	Depth to water (ft.)	Recharge in./yr.	Aquifer Media	Soil Media	Topography % Slope	Vadose Zone Media	Hydro. Cond.	Rating
7Ae01	50-75	2-4	Massive Shale	Clay Loam	0-2	Silt/Clay	1-100	67
7Ae02	50-75	2-4	Massive Shale	Silty Loam	0-2	Silt/Clay	1-100	69
7Ae03	50-75	2-4	Massive Shale	Sandy Loam	0-2	Silt/Clay	1-100	73
7Ae04	50-75	2-4	Massive Shale	S/S Clay	0-2	Silt/Clay	1-100	75
7Ae05	15-30	4-7	Massive Shale	S/S Clay	0-2	Silt/Clay	1-100	112
7Ae06	15-30	4-7	Massive Shale	S/S Clay	12-18	Silt/Clay	1-100	105
7Ae07	30-50	2-4	Massive Shale	Sandy Loam	2-6	Silt/Clay	1-100	82
7Ae08	15-30	4-7	Sand and Gravel	S/S Clay	0-2	Snd. & Gr.	100-300	129
7Ae09	30-50	2-4	Massive Shale	Sandy Loam	0-2	Silt/Clay	1-100	83
7Ae10	30-50	2-4	Massive Shale	S/S Clay	2-6	Silt/Clay	1-100	84
7Ae11	30-50	2-4	Massive Shale	S/S Clay	0-2	Silt/Clay	1-100	85
7Ae12	5-15	4-7	Massive Shale	S/S Clay	0-2	Snd. & Gr.	1-100	127
7Ae13	50-75	2-4	Sand and Gravel	Sandy Loam	0-2	Silt/Clay	100-300	88
7Ae14	50-75	2-4	Sand and Gravel	S/S Clay	0-2	Silt/Clay	100-300	90
7Ae15	15-30	4-7	Massive Shale	S/S Clay	0-2	Snd. & Gr.	1-100	117
7Ae16	15-30	2-4	Massive Shale	Loam	0-2	Silt/Clay	1-100	91
7Ae17	50-75	4-7	Massive Shale	Sandy Loam	0-2	Snd. & Gr.	1-100	95
7Ae18	15-30	2-4	Massive Shale	S/S Clay	0-2	Silt/Clay	1-100	95
7Ae19	15-30	2-4	Massive Shale	Loam	0-2	Snd. & Gr.	1-100	101
7Ae20	50-75	4-7	Massive Shale	S/S Clay	0-2	Snd. & Gr.	1-100	97
7Ae21	15-30	2-4	Massive Shale	Loam	0-2	Silt/Clay	1-100	96
7Ae22	15-30	2-4	Massive Shale	S/S Clay	0-2	Silt/Clay	1-100	100
7Ae23	30-50	2-4	Sand and Gravel	S/S Clay	0-2	Silt/Clay	100-300	102
7Ae24	15-30	4-7	Massive Shale	Sandy Loam	2-6	Snd. & Gr.	1-100	114
7Ae25	15-30	2-4	Sand and Gravel	S/S Clay	0-2	Silt/Clay	100-300	112
7Ae26	50-75	4-7	Sand and Gravel	S/S Clay	0-2	Snd. & Gr.	100-300	112
7Ae27	30-50	4-7	Massive Shale	S/S Clay	2-6	Snd. & Gr.	1-100	106
7Ae28	30-50	4-7	Massive Shale	S/S Clay	0-2	Snd. & Gr.	1-100	107
7Ae29	5-15	2-4	Massive Shale	S/S Clay	0-2	Silt/Clay	1-100	110
7Ae30	50-75	4-7	Sand and Gravel	Sandy Loam	0-2	Snd. & Gr.	100-300	110



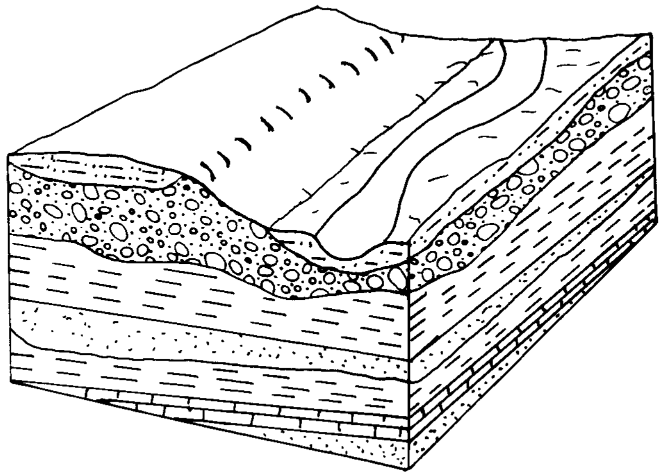
7Af-Sand and Gravel Interbedded in Glacial Till

This hydrogeologic setting is limited to the extreme southeastern corner of Henry County along the boundary of Wood County. The area is characterized by flat-lying topography and very low relief. The vadose zone is composed of silty to clayey glacial till. The till may be fractured or jointed, particularly in areas where it is predominantly thin and weathered. Depth to water is usually shallow, averaging less than 30 feet. Soils are generally shrink-swell (aggregated) clays. The aquifer consists of thin lenses of sand and gravel interbedded in the glacial till. Groundwater yields range from 5 to 25 gpm. Recharge is moderate due to the relatively shallow depth to water, flatter topography, and the relatively low permeability of the clayey soils and vadose.

The GWPP index value for the hydrogeologic setting of Sand and Gravel Interbedded in Glacial Till is 129 with the total number of GWPP index calculations equaling 1.

Hydrogeologic Setting Values for: 7Af-Sand and Gravel interbedded in Glacial Till

Setting	Depth to water (ft.)	Recharge in./yr.	Aquifer Media	Soil Media	Topography % Slope	Vadose Zone Media	Hydro. Cond.	Rating
7Af1	15-30	4-7	Sand and Gravel	S/S Clay	0-2	Silt/Clay	100-300	129



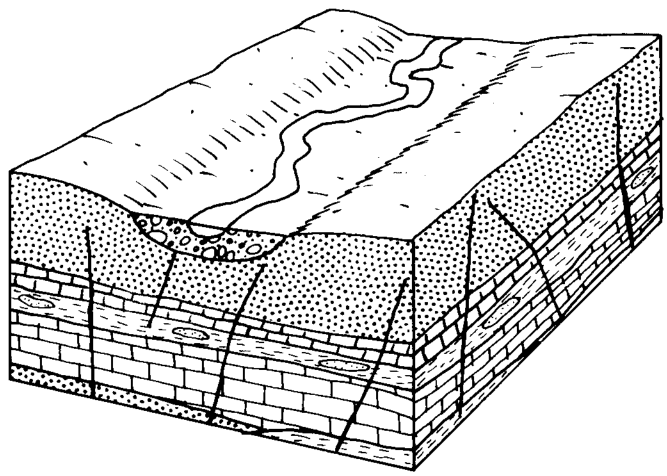
7Ea-River Alluvium with Overbank Deposits

This hydrogeologic setting is associated with floodplains and terraces flanking the Maumee River and other major tributaries in the county. Relatively broad, flat-lying floodplains and low terraces characterize this setting. Vadose zone materials vary from clayey to silty floodplain deposits to sandy and loamy materials in the terraces. Wells may be developed in sand and gravel lenses underlying the floodplains and terraces. These lenses are interbedded with finer-grained alluvium, till, or lacustrine deposits. Where these coarser lenses are lacking, wells are completed in the underlying shale or limestone bedrock. Yields vary from a range of 25 to 100 gpm for Silurian limestones, to 5 to 25 gpm for Devonian limestones and less than 5 gpm for shales. The thin sand and gravel lenses commonly have yields of 5 to 25 gpm. Soils are generally loams on terraces and silt loams on floodplains. The depth to water is typically shallow averaging less than 35 feet. Depth to water typically increases in the headwaters of tributaries. Recharge is typically moderate to high due to shallow depth to water, flat topography, presence of nearby streams and low to moderate permeability soils and vadose zone materials.

GWPP index values for the hydrogeologic setting of River Alluvium with Overbank Deposits range from 95 to 151 with the total number of GWPP index calculations equaling 36.

Hydrogeologic Setting Values for: 7Ea-River Alluvium with Overbank Deposits

Setting	Depth to water (ft.)	Recharge in./yr.	Aquifer Media	Soil Media	Topography % Slope	Vadose Zone Media	Hydro. Cond.	Rating
7Ea1	15-30	4-7	Massive Shale	S/S Clay	2-6	Snd. & Gr.	1-100	116
7Ea2	15-30	4-7	Massive Shale	S/S Clay	0-2	Snd. & Gr.	1-100	117
7Ea3	30-50	4-7	Massive Shale	Silty Loam	2-6	Silt/Clay	1-100	95
7Ea4	15-30	4-7	Sand and Gravel	S/S Clay	2-6	Snd. & Gr.	100-300	128
7Ea5	15-30	4-7	Sand and Gravel	Silty Loam	0-2	Snd. & Gr.	100-300	126
7Ea6	15-30	4-7	Massive Shale	Sandy Loam	2-6	Snd. & Gr.	1-100	114
7Ea7	30-50	4-7	Massive Shale	Silty Loam	2-6	Snd. & Gr.	1-100	100
7Ea8	15-30	4-7	Sand and Gravel	Sandy Loam	2-6	Snd. & Gr.	100-300	126
7Ea9	15-30	4-7	Sand and Gravel	Loam	0-2	Silt/Clay	100-300	120
7Ea10	5-15	4-7	Massive Shale	Loam	0-2	Snd. & Gr.	1-100	117
7Ea11	30-50	4-7	Massive Shale	Silty Loam	0-2	Silt/Clay	1-100	96
7Ea12	15-30	4-7	Massive Shale	Silty Loam	2-6	Silt/Clay	1-100	105
7Ea13	15-30	4-7	Massive Shale	Silty Loam	0-2	Silt/Clay	1-100	106
7Ea14	30-50	4-7	Massive Shale	Sandy Loam	0-2	Snd. & Gr.	1-100	105
7Ea15	15-30	4-7	Massive Limestone	Silty Loam	0-2	Silt/Clay	100-300	127
7Ea16	0-5	7-10	Sand and Gravel	Loam	0-2	Snd. & Gr.	100-300	151
7Ea17	0-5	7-10	Sand and Gravel	Silty Loam	0-2	Snd. & Gr.	100-300	149
7Ea18	30-50	4-7	Massive Shale	Loam	2-6	Snd. & Gr.	1-100	102
7Ea19	15-30	7-10	Massive Limestone	Loam	0-2	Snd. & Gr.	100-300	139
7Ea20	15-30	4-7	Massive Limestone	Loam	2-6	Snd. & Gr.	100-300	130
7Ea21	15-30	4-7	Massive Limestone	Silty Loam	0-2	Snd. & Gr.	100-300	129
7Ea22	15-30	4-7	Massive Shale	Clay Loam	2-6	Snd. & Gr.	1-100	108
7Ea23	15-30	4-7	Sand and Gravel	Loam	0-2	Snd. & Gr.	100-300	128
7Ea24	15-30	4-7	Massive Limestone	Silty Loam	2-6	Snd. & Gr.	100-300	128
7Ea25	15-30	4-7	Massive Shale	Silty Loam	0-2	Snd. & Gr.	1-100	111
7Ea26	15-30	4-7	Sand and Gravel	Silty Loam	0-2	Silt/Clay	100-300	124
7Ea27	15-30	4-7	Massive Shale	Loam	2-6	Snd. & Gr.	1-100	112
7Ea28	15-30	4-7	Massive Limestone	Loam	2-6	Silt/Clay	100-300	125
7Ea29	15-30	4-7	Massive Shale	Loam	0-2	Snd. & Gr.	1-100	113
7Ea30	5-15	4-7	Sand and Gravel	Clay Loam	0-2	Silt/Clay	100-300	126
7Ea31	15-30	4-7	Massive Limestone	Loam	0-2	Silt/Clay	100-300	126
7Ea32	15-30	4-7	Sand and Gravel	Loam	0-2	Snd. & Gr.	100-300	125
7Ea33	5-15	4-7	Massive Limestone	Silty Loam	0-2	Silt/Clay	100-300	134
7Ea34	5-15	4-7	Massive Shale	Loam	2-6	Snd. & Gr.	1-100	122
7Ea35	15-30	4-7	Sand and Gravel	Silty Loam	0-2	Snd. & Gr.	100-300	123
7Ea36	5-15	4-7	Massive Limestone	Loam	0-2	Silt/Clay	100-300	136



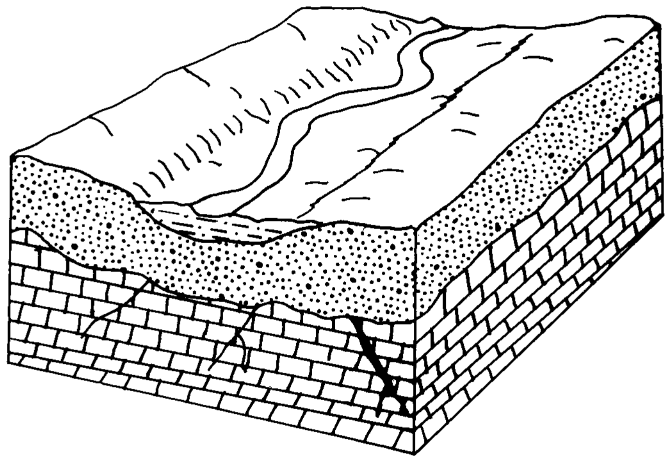
7Eb-River Alluvium without Overbank Deposits

This hydrogeologic setting consists of relatively broad, higher-level terraces that flank the Maumee River. These terraces are found east of Napoleon. This setting is similar to the 7Ea-River Alluvium with Overbank Deposits except that the terrace has no overlying fine-grained floodplain deposits. Vadose zone media consists of bedded sand and gravel interbedded with thin silt and clay. Soils are gravel and lack fines. The aquifer is sand and gravel lenses underlying the terraces. Yields average 25 to 100 gpm. Depth to water is shallow due to the proximity of the Maumee River. Recharge is moderately high due to the relatively permeable soils and vadose, shallow depth to water, and flat topography.

The GWPP index value for the hydrogeologic setting of River Alluvium without Overbank Deposits is 148 with the total number of GWPP index calculations equaling 1.

Hydrogeologic Setting Values for: 7Eb- River Alluvium without Overbank Deposits

Setting	Depth to water (ft.)	Recharge in./yr.	Aquifer Media	Soil Media	Topography % Slope	Vadose Zone Media	Hydro. Cond.	Rating
7Eb1	5-15	4-7	Sand and Gravel	Gravel	0-2	Snd. & Gr.	100-300	148



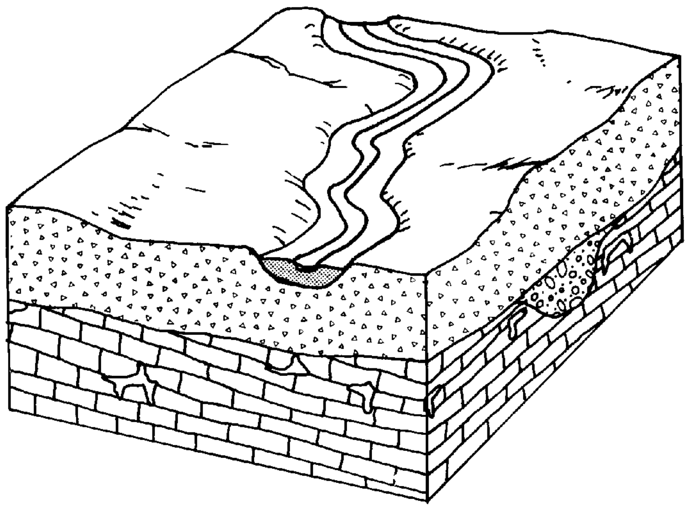
7Ec-Alluvium over Sedimentary Rock

This hydrogeologic setting is limited to the floodplain immediately adjacent to the Maumee River. This setting is limited to the eastern Margin of Henry County and borders Wood County. This setting is similar to the 7Ea-River Alluvium with Overbank Deposits except that the alluvial deposits are thin and directly overlie the limestone bedrock. The vadose zone consists of the silty to clayey alluvial deposits. Yields ranging from 25-100 gpm are obtained from the underlying limestone bedrock. The alluvium is probably in direct hydraulic connection with the underlying bedrock. The limestone is likely to be fractured and contain solution features. Streams may be in direct hydraulic connection with the underlying aquifer. Soils on the floodplain are typically silt loams derived from the alluvium. Recharge is typically relatively high due to the flat-lying topography, shallow depth to water, the moderate permeability of the soils, and the relatively high permeability of the limestone.

The GWPP index value for the hydrogeologic setting Alluvium over Sedimentary Rocks is 134 with the total number of GWPP index calculations equaling 1.

Hydrogeologic Setting Values for: 7Ec- Alluvium over Sedimentary Rock

Setting	Depth to water (ft.)	Recharge in./yr.	Aquifer Media	Soil Media	Topography % Slope	Vadose Zone Media	Hydro. Cond.	Rating
7Ec1	5-15	4-7	Massive Limestone	Silty Loam	0-2	Silt/Clay	100-300	134

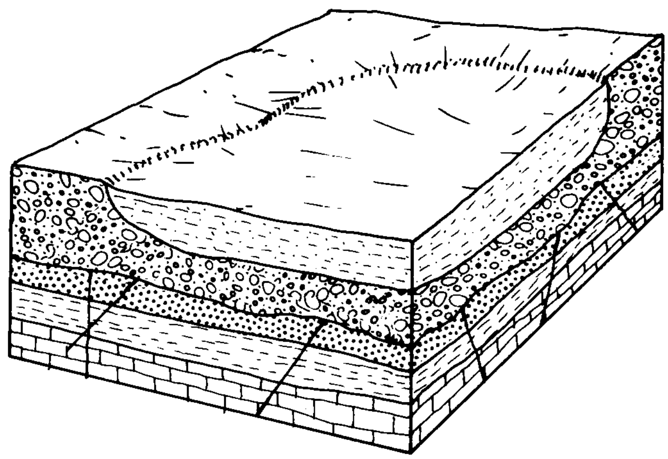


7Ed Alluvium Over Glacial Till

This hydrogeologic setting is comprised of flat-lying floodplains and stream terraces containing thin to moderate thicknesses of modern alluvium. This setting is similar to the 7Af–Sand and Gravel interbedded in Glacial Till setting except for the presence of the modern stream and related deposits. This setting is found along the eastern margin of the Henry County, bordering Wood County. The stream may or may not be in direct hydraulic connection with the underlying sand and gravel lenses, which constitute the aquifer. Wells not completed in sand and gravel lenses are completed in the underlying limestone. The surficial, silty alluvium is typically more permeable than the underlying till. The alluvium is too thin to be considered the aquifer. Soils are silt loams. Yields commonly range from 10 to 25 gpm from the sand and gravel and 25 to 100 gpm for the underlying limestone. Depth to water is typically shallow with depths averaging less than 20 feet. Recharge is moderately high due to the shallow depth to water, flat-lying topography, and the moderate permeability of the glacial till and alluvium.The GWPP index value for the hydrogeologic setting Alluvium Over Glacial Till is 152 with the total number of GWPP index calculations equaling 1.

Hydrogeologic Setting Values for: 7Ed- Alluvium over Glacial Till

Setting	Depth to water (ft.)	Recharge in./yr.	Aquifer Media	Soil Media	Topography % Slope	Vadose Zone Media	Hydro. Cond.	Rating
7Ed1	5-15	7-10	Massive Limestone	Silty Loam	0-2	Snd. & Gr.	100-300	152



7F Glacial Lake Plains Deposits

This hydrogeologic setting is characterized by flat-lying topography and varying thicknesses of fine-grained lacustrine sediments. These sediments were deposited in lakes and deltas by a sequence of ancestral lakes. This setting is common in northeastern and north central Henry County. The vadose zone media consists of silty to clayey lacustrine sediments or silty deltaic sediments that overlie glacial till. The aquifer consists of thin sand and gravel lenses interbedded in the underlying till or in the underlying shale or limestone bedrock. Yields are usually less than 5 gpm for the shale, 5 to 25 gpm for the sand and gravel lenses, and 25 to 100 gpm for the limestone. Depth to water is commonly shallow to moderate with depths increasing away from the Maumee River. Soils are shrink-swell (aggregated) clays or clay loams derived from clayey lacustrine sediments and silt loams and sandy loams derived from deltaic sediments. The presence of shrink-swell clay soils is important due to the fact that desiccation cracks in these soils form during prolonged dry spells. These cracks serve as conduits for contaminants to move through these normally low permeability soils. Recharge in this setting is low to moderate due to the relatively shallow depth to water, flat-lying topography, and the low permeability soils and vadose.

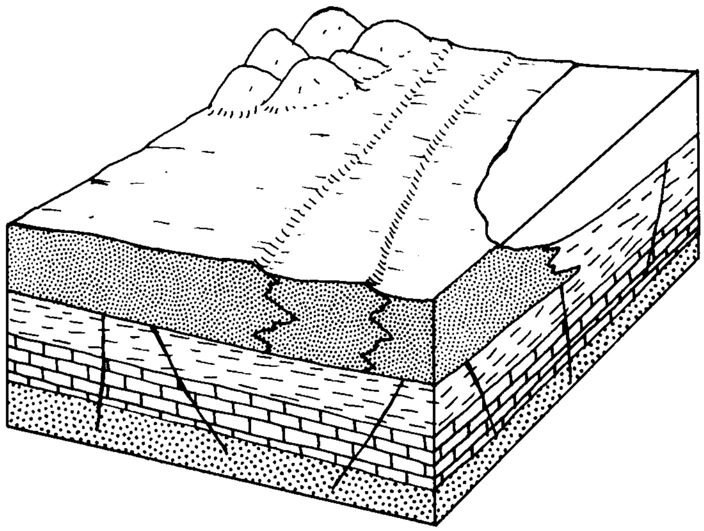
GWPP index values for the hydrogeologic setting of Glacial Lake Plains Deposits range from 86 to 143 with the total number of GWPP index calculations equaling 51.

Hydrogeologic Setting Values for: 7F-Glacial Lake Plains Deposits

Setting	Depth to water (ft.)	Recharge in./yr.	Aquifer Media	Soil Media	Topography % Slope	Vadose Zone Media	Hydro. Cond.	Rating
7F1	30-50	4-7	Sand and Gravel	Sandy Loam	0-2	Snd. & Gr.	100-300	117
7F2	30-50	2-4	Massive Shale	Loam	0-2	Silt/Clay	1-100	86
7F3	15-30	2-4	Massive Limestone	Clay Loam	0-2	Silt/Clay	100-300	110
7F4	15-30	2-4	Massive Shale	Loam	0-2	Silt/Clay	1-100	96
7F5	15-30	2-4	Massive Shale	Sandy Loam	2-6	Silt/Clay	1-100	97
7F6	15-30	2-4	Massive Shale	Sandy Loam	0-2	Silt/Clay	1-100	98
7F7	15-30	2-4	Massive Shale	S/S Clay	2-6	Silt/Clay	1-100	99
7F8	30-50	2-4	Sand and Gravel	Sandy Loam	0-2	Silt/Clay	100-300	100
7F9	15-30	2-4	Massive Shale	S/S Clay	0-2	Silt/Clay	1-100	100
7F10	15-30	2-4	Massive Shale	Clay Loam	0-2	Silt/Clay	1-100	92
7F11	30-50	4-7	Massive Shale	Sandy Loam	0-2	Snd. & Gr.	1-100	105
7F12	5-15	2-4	Massive Shale	Loam	0-2	Silt/Clay	1-100	106
7F13	30-50	2-4	Massive Limestone	Sandy Loam	0-2	Silt/Clay	100-300	106
7F14	15-30	4-7	Massive Shale	S/S Clay	0-2	Snd. & Gr.	1-100	117
7F15	15-30	4-7	Massive Shale	S/S Clay	18+	Snd. & Gr.	1-100	108
7F16	30-50	2-4	Massive Limestone	S/S Clay	0-2	Silt/Clay	100-300	108
7F17	15-30	4-7	Massive Shale	Clay Loam	0-2	Snd. & Gr.	1-100	109
7F18	15-30	4-7	Massive Shale	Clay Loam	2-6	Snd. & Gr.	1-100	118
7F19	15-30	2-4	Sand and Gravel	Sandy Loam	0-2	Silt/Clay	100-300	110
7F20	5-15	2-4	Massive Shale	S/S Clay	0-2	Silt/Clay	1-100	110
7F21	5-15	4-7	Sand and Gravel	S/S Clay	2-6	Snd. & Gr.	100-300	141
7F22	15-30	2-4	Sand and Gravel	S/S Clay	0-2	Silt/Clay	100-300	112
7F23	15-30	2-4	Massive Limestone	Loam	2-6	Silt/Clay	100-300	113
7F24	15-30	4-7	Massive Shale	Loam	0-2	Snd. & Gr.	1-100	113
7F25	15-30	2-4	Massive Shale	Clay Loam	2-6	Silt/Clay	1-100	91
7F26	5-15	2-4	Massive Limestone	Clay Loam	6-12	Silt/Clay	100-300	115
7F27	5-15	4-7	Sand and Gravel	Sandy Loam	0-2	Snd. & Gr.	100-300	140
7F28	15-30	4-7	Massive Shale	Sandy Loam	0-2	Snd. & Gr.	1-100	115
7F29	15-30	4-7	Massive Shale	S/S Clay	2-6	Snd. & Gr.	1-100	116
7F30	15-30	4-7	Massive Shale	S/S Clay	2-6	Snd. & Gr.	1-100	116
7F31	15-30	2-4	Massive Limestone	S/S Clay	2-6	Silt/Clay	100-300	117
7F32	15-30	4-7	Massive Shale	S/S Clay	0-2	Snd. & Gr.	1-100	117
7F33	15-30	4-7	Sand and Gravel	S/S Clay	0-2	Silt/Clay	100-300	130
7F34	15-30	4-7	Massive Limestone	Sandy Loam	0-2	Snd. & Gr.	100-300	133
7F35	15-30	2-4	Massive Limestone	S/S Clay	2-6	Snd. & Gr.	100-300	122
7F36	5-15	4-7	Massive Limestone	Sandy Loam	0-2	Snd. & Gr.	100-300	143
7F37	30-50	4-7	Massive Limestone	Sandy Loam	0-2	Snd. & Gr.	100-300	123
7F38	15-30	4-7	Sand and Gravel	Silty Loam	2-6	Snd. & Gr.	100-300	125
7F39	5-15	4-7	Sand and Gravel	S/S Clay	0-2	Snd. & Gr.	100-300	142
7F40	15-30	4-7	Massive Limestone	S/S Clay	0-2	Snd. & Gr.	100-300	135

Hydrogeologic Setting Values for: 7F-Glacial Lake Plains Deposits (cont.)

Setting	Depth to water (ft.)	Recharge in./yr.	Aquifer Media	Soil Media	Topography % Slope	Vadose Zone Media	Hydro. Cond.	Rating
7F41	15-30	4-7	Sand and Gravel	Sandy Loam	0-2	Snd. & Gr.	100-300	127
7F42	5-15	4-7	Massive Shale	S/S Clay	0-2	Snd. & Gr.	1-100	127
7F43	5-15	2-4	Massive Limestone	S/S Clay	0-2	Silt/Clay	100-300	128
7F43	5-15	2-4	Massive Limestone	S/S Clay	0-2	Silt/Clay	100-300	128
7F44	15-30	4-7	Sand and Gravel	S/S Clay	0-2	Snd. & Gr.	100-300	129
7F45	15-30	4-7	Massive Limestone	S/S Clay	6-12	Snd. & Gr.	100-300	130
7F46	15-30	4-7	Sand and Gravel	Sandy Loam	0-2	Snd. & Gr.	100-300	130
7F47	15-30	4-7	Massive Limestone	S/S Clay	2-6	Snd. & Gr.	100-300	134
7F48	15-30	4-7	Massive Limestone	Loam	0-2	Snd. & Gr.	100-300	131
7F49	15-30	4-7	Massive Limestone	Sandy Loam	0-2	Snd. & Gr.	100-300	133
7F50	15-30	4-7	Massive Limestone	Sandy Loam	2-6	Snd. & Gr.	100-300	132
7F51	15-30	4-7	Sand and Gravel	S/S Clay	0-2	Snd. & Gr.	100-300	132



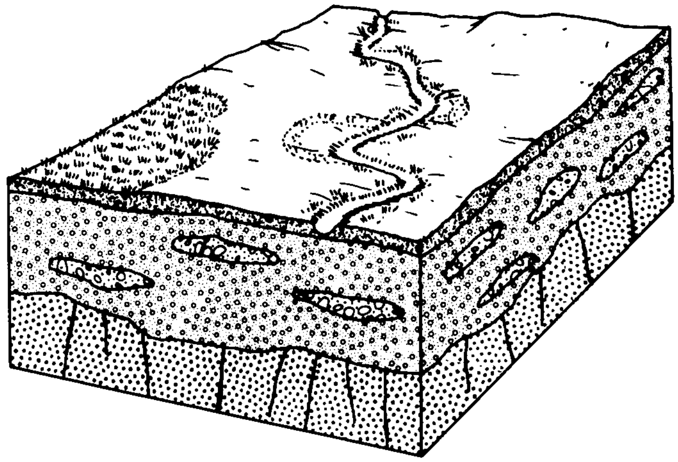
7H-Beaches,Beach Ridge, and Sand Dunes

This hydrogeologic setting is characterized by narrow, elongate, low-lying ridges of sand overlying the lacustrine plain or wave-planed till uplands. This setting is common in the northeastern corner of the county and the central portion of the county south of the Maumee River. The thick beach/deltaic deposits in the northeastern corner are referred to as the Oak Openings. The vadose zone media is composed of clean, fine-grained quartz sand that has high permeability and low sorptive capability. Where the beach deposits are thin, the vadose zone may include some underlying clayey to silty glacial till or lacustrine deposits. Ground water, particularly in the Oak Openings is obtained from sand and gravel lenses found at the base of the beach deposits. Dug wells and well point are common in these thin, surficial deposits. Where coarse materials are lacking, wells are completed in sand and gravel lenses interbedded with the underlying till or in underlying shale or limestone bedrock. Depth to water is typically fairly shallow, particularly if the beach ridge itself is the shallow aquifer. Soils are sand or sandy loams. Recharge is highly variable; recharge is high for shallow, surficial beach ridge aquifers due to shallow depth to water and highly permeable soils and vadose. Recharge is moderate where the aquifers and depth to water are deeper and where finer-grained lacustrine or till vadose zone media underlie thin beach deposits.

GWPP index values for the hydrogeologic setting of Beaches, Beach Ridges, and Sand Dunes range from 94 to 173 with the total number of GWPP index calculations equaling 32.

Hydrogeologic Setting Values for: 7H-Beach Ridges and Sand Dunes

Setting	Depth to water (ft.)	Recharge in./yr.	Aquifer Media	Soil Media	Topography % Slope	Vadose Zone Media	Hydro. Cond.	Rating
7H1	15-30	4-7	Massive Limestone	Sandy Loam	0-2	Snd. & Gr.	100-300	133
7H2	5-15	10+	Sand and Gravel	Gravel	0-2	Snd. & Gr.	100-300	173
7H3	5-15	10+	Sand and Gravel	Gravel	2-6	Snd. & Gr.	100-300	172
7H4	30-50	4-7	Massive Shale	Sandy Loam	2-6	Snd. & Gr.	1-100	104
7H5	5-15	10+	Sand and Gravel	Sand	0-2	Snd. & Gr.	100-300	171
7H6	5-15	10+	Sand and Gravel	Sand	2-6	Snd. & Gr.	100-300	170
7H7	30-50	2-4	Massive Shale	Sand	0-2	Silt/Clay	1-100	94
7H8	5-15	10+	Sand and Gravel	Sand	0-2	Snd. & Gr.	100-300	171
7H9	5-15	10+	Sand and Gravel	Sand	6-12	Snd. & Gr.	100-300	166
7H10	30-50	2-4	Massive Limestone	Sandy Loam	2-6	Silt/Clay	100-300	100
7H11	30-50	2-4	Massive Limestone	Sandy Loam	0-2	Silt/Clay	100-300	101
7H12	30-50	2-4	Massive Limestone	Sandy Loam	2-6	Silt/Clay	100-300	105
7H13	5-15	10+	Sand and Gravel	Sandy Loam	0-2	Snd. & Gr.	100-300	165
7H14	15-30	2-4	Massive Limestone	Loam	2-6	Silt/Clay	100-300	113
7H15	15-30	4-7	Massive Shale	Sandy Loam	2-6	Snd. & Gr.	1-100	114
7H16	15-30	4-7	Massive Shale	Sandy Loam	0-2	Snd. & Gr.	1-100	115
7H17	5-15	10+	Sand and Gravel	Loam	2-6	Snd. & Gr.	100-300	162
7H18	15-30	4-7	Massive Shale	Sand	2-6	Snd. & Gr.	1-100	120
7H19	15-30	4-7	Massive Shale	Sand	0-2	Snd. & Gr.	1-100	121
7H20	15-30	7-10	Massive Limestone	Sand	0-2	Snd. & Gr.	100-300	157
7H21	30-50	4-7	Massive Limestone	Sandy Loam	2-6	Snd. & Gr.	100-300	122
7H22	15-30	4-7	Sand and Gravel	Sandy Loam	2-6	Snd. & Gr.	100-300	126
7H23	5-15	4-7	Massive Limestone	Sandy Loam	0-2	Silt/Clay	100-300	138
7H24	15-30	4-7	Massive Limestone	Sandy Loam	2-6	Silt/Clay	100-300	127
7H25	30-50	4-7	Massive Limestone	Sand	0-2	Snd. & Gr.	100-300	129
7H26	5-15	4-7	Massive Shale	Sand	2-6	Snd. & Gr.	1-100	130
7H27	15-30	4-7	Sand and Gravel	Sandy Loam	0-2	Snd. & Gr.	100-300	130
7H28	15-30	7-10	Massive Limestone	Sand	0-2	Snd. & Gr.	100-300	152
7H29	15-30	7-10	Massive Shale	Sand	2-6	Snd. & Gr.	1-100	133
7H30	15-30	7-10	Sand and Gravel	Sand	2-6	Snd. & Gr.	100-300	151
7H31	15-30	7-10	Massive Limestone	Sandy Loam	0-2	Snd. & Gr.	100-300	146
7H32	15-30	7-10	Sand and Gravel	Sand	6-12	Snd. & Gr.	100-300	147

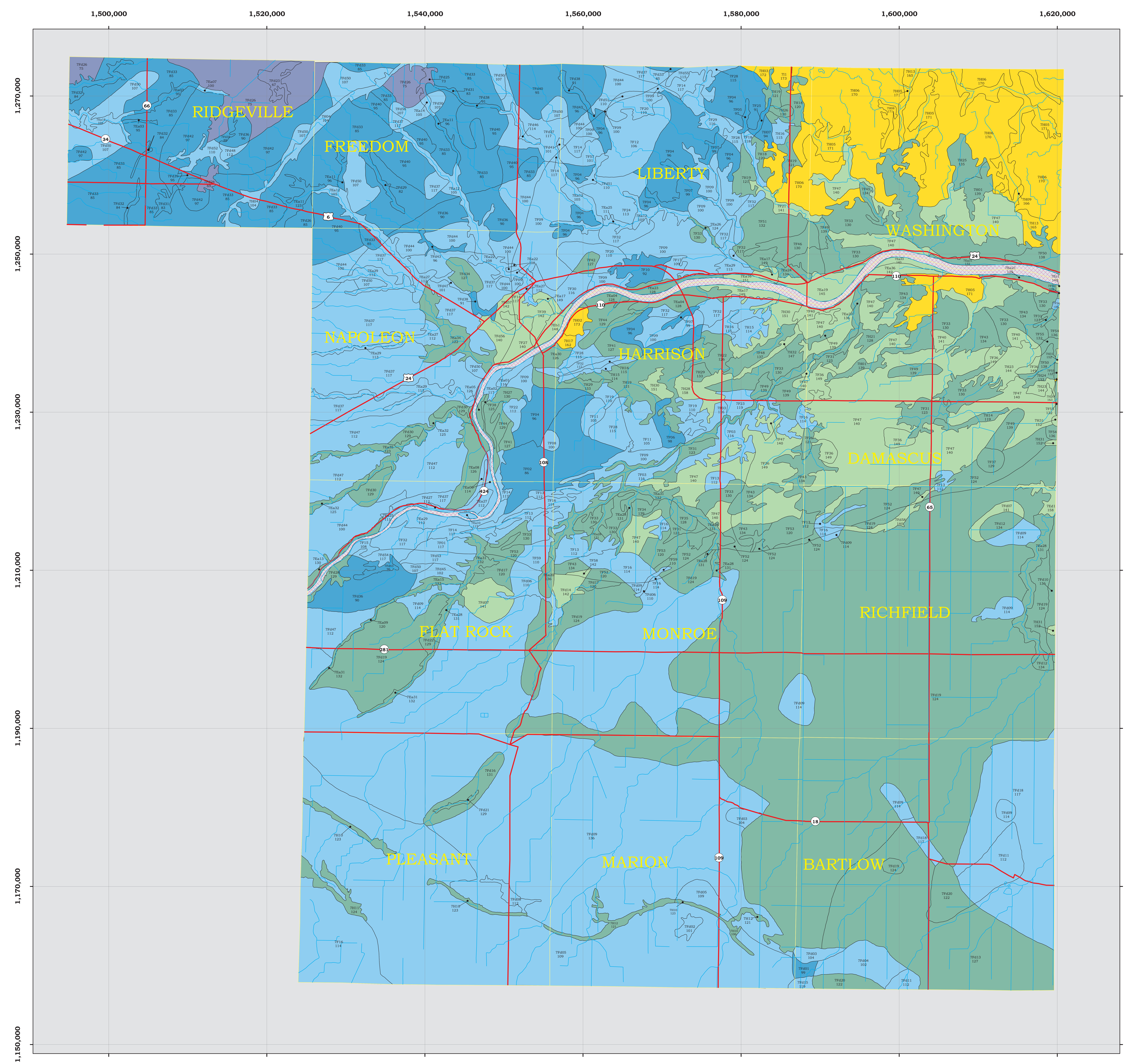


7I-Marshes and Swamps

This hydrogeologic setting is characterized by extremely low topographic relief, high water table, poor drainage, and thin, organic-rich silt and clay deposits. This setting is limited to a low; depress ional area encircled by beach ridge deposits associated with the Oak Openings. This depressional area borders Fulton County. In this setting, thin peat and organic-rich silt and clay deposits overlie gravel soils and vadose zone media. The aquifer is sand and gravel lenses that underlie the surface. Depth to water is very shallow due to the high water table. Recharge is high due to the shallow depth to water and highly permeable vadose and aquifer. The GWPP index values for the hydrogeologic setting of Swamps/Marshes is 173 with the total number of GWPP index calculations equaling 1.

Hydrogeologic Setting Values for: 7I-Marshes and Swamps

Setting	Depth to water (ft.)	Recharge in./yr.	Aquifer Media	Soil Media	Topography % Slope	Vadose Zone Media	Hydro. Cond.	Rating
7I1	5-15	10+	Sand and Gravel	Gravel	0-2	Snd. & Gr.	100-300	173



Ground Water Pollution Potential of Henry County

by

Kathy Sprowls

Ohio Department of Natural Resources

Divison of Soil and Water Resources

After Miller, Harrell, and Angle, 2002

Ground Water Pollution Potential maps are designed to evaluate the susceptibility of ground water to contamination from surface sources. These maps are based on the DRASTIC system developed for the USEPA (Aller et al., 1987). The DRASTIC system consists of two major elements: the designation of mappable units, termed hydrogeologic settings, and a relative rating system for determining the ground water pollution potential within a hydrogeologic setting. The application of DRASTIC to an area requires the recognition of a set of assumptions made in the development of the system. The evaluation of pollution potential of an area assumes that a contaminant with the mobility of water is introduced at the surface and is flushed into the ground water by precipitation. DRASTIC is not designed to replace specific on-site investigations.

In DRASTIC mapping, hydrogeologic settings form the basis of the system and incorporate the major hydrogeologic factors that affect and control ground water movement and occurrence. The relative rating system is based on seven hydrogeologic factors: Depth to water, net Recharge, Aquifer media, Soil media, Topography, Impact of the vadose zone media, and hydraulic Conductivity. These factors form the acronym DRASTIC. The relative rating system uses a combination of weights and ratings to produce a numerical value called the ground water pollution potential index. Higher index values indicate higher susceptibility to ground water contamination. Polygons (outlined in black on the map at left) are regions where the hydrogeologic setting and the pollution potential index are combined to create a mappable unit with specific hydrogeologic characteristics, which determine the region's relative vulnerability to contamination. Additional information on the DRASTIC system, hydrogeologic settings, ratings, and weighting factors is included in the report.

Description of Map Symbols

Hydrogeologic Region → 7D24 ← Hydrogeologic Setting

147 ← Relative Pollution Potential

Legend

Colors are used to depict the ranges in the pollution potential indexes shown below. Warm colors (red, orange, yellow) represent areas of higher vulnerability (higher pollution potential indexes), while cool colors (green, blue, violet) represent areas of lower vulnerability to contamination (lower pollution potential indexes).

Roads

Streams

Townships

Index Ranges

- Not Rated
- Less Than 79
- 80 - 99
- 100 - 119
- 120 - 139
- 140 - 159
- 160 - 179
- 180 - 199
- Greater Than 200

N

Black grid represents the State Plane South Coordinate System (NAD27, feet).

0 1 2 3 4 5

Miles

0 2 4 6 8

Kilometers

Ohio Department of Natural Resources
Division of Soil and Water Resources
Water Resources Section
2045 Morse Road
Columbus Ohio 43229-6605
www.dnr.state.oh.us
Revised
February 2011

Cartography by Robert Baker