GROUND WATER POLLUTION POTENTIAL OF HENRY COUNTY, OHIO

BY

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

AND

MICHAEL P. ANGLE

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BY

KATHY SPROWLS

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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 Lower Mississippian and Upper 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.

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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

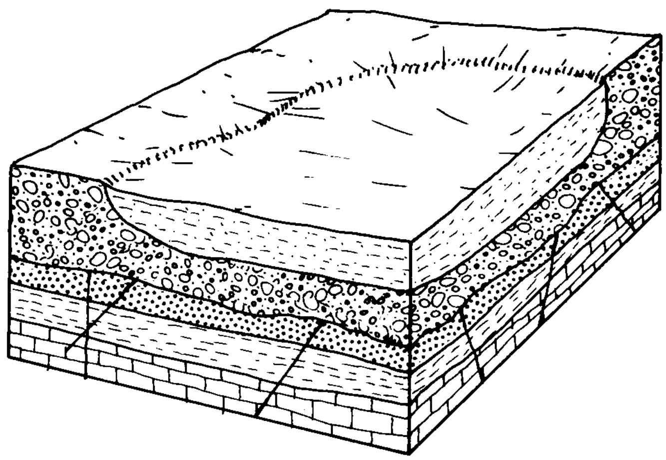
C – Conductivity (Hydraulic) of the Aquifer

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.



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.

Figure 1. Format and description of the hydrogeologic setting – 7F Glacial Lake Plains Deposits

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 vulnerability of an area to contamination increases as the DRASTIC index increases. 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	

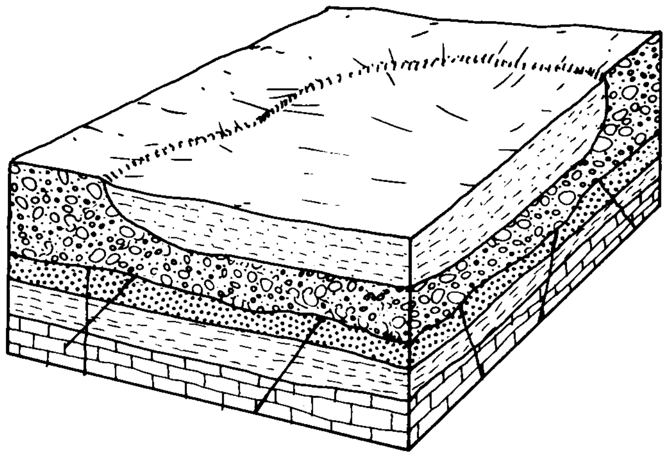
TABLE 8. RANGES AND RATINGS FOR HYDRAULIC CONDUCTIVITY

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 **7F1**, 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 **117**. 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 7F1		GENERAL		
FEATURE	RANGE	WEIGHT	RATING	NUMBER
Depth to Water	30-50	5	5	25
Net Recharge	4-7	4	6	24
Aquifer Media	Sand and Gravel	3	5	15
Soil Media	Sandy Loam	2	6	12
Topography	0-2%	1	10	10
Impact of Vadose Zone	Sand & Gravel w/Silt & Clay	5	5	25
Hydraulic Conductivity	100-300	3	2	6
		DRASTIC	INDEX	117

Figure 2. Description of the hydrogeologic setting – 7F1 Glacial Lake Plains Deposits

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. Greater the susceptibility to contamination is indicated by a higher pollution potential index. 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:

7F1 - defines the hydrogeologic region and setting
117 - defines the relative pollution potential

Here the first number (**7**) refers to the major hydrogeologic region and the upper and lower case letters (**F**) 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 (**117**) 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 Huron-Erie Lake Plains section of the Central Lowland Province (Brockman, 1998). 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). The late Wisconsinan Ice Sheet deposited the surficial till in Henry County (Goldthwait et al., 1961 and Pavey et al., 1999). 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 Soil and Water Resources, 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

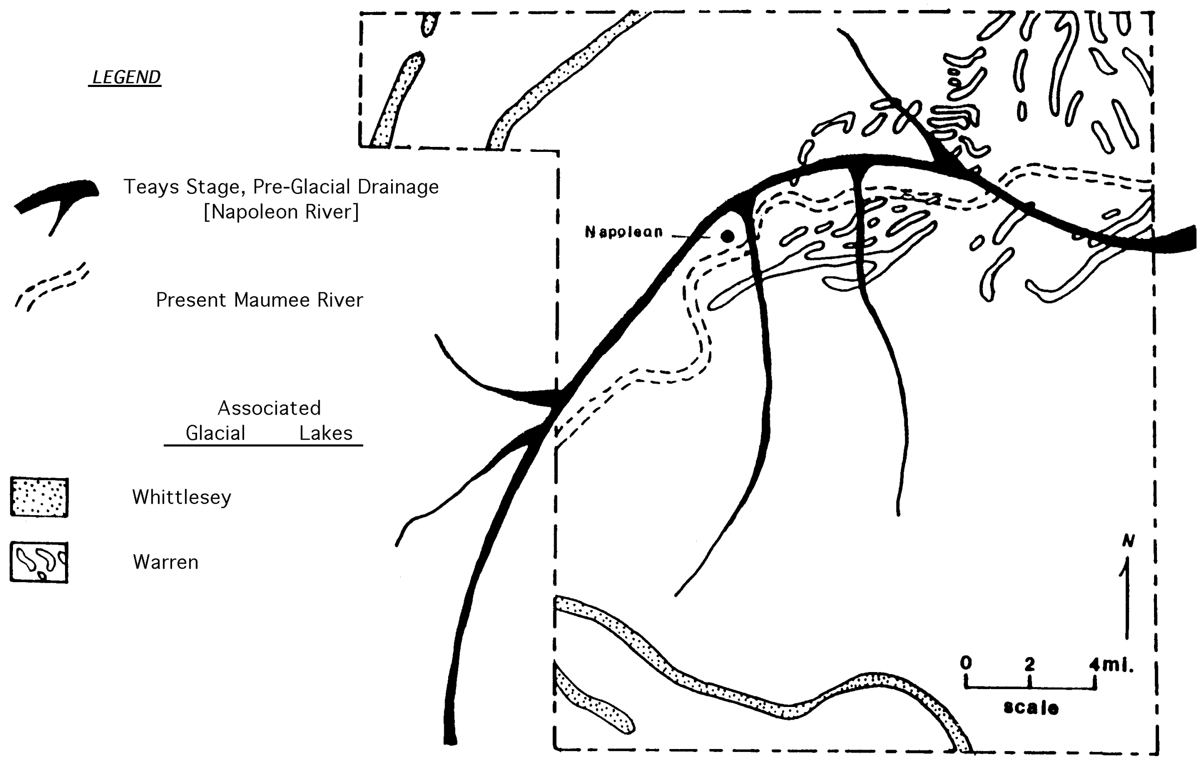


Figure 4. Location of Teays preglacial river valleys and Wisconsinan age beaches and sand bars in Henry County, Ohio (after Miller, 1997 and Palombo, 1983)

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 available for the entire county done on a 1:24,000 USGS topographic map base. The ODNR, Division of Soil and Water Resources, 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 Miller, 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 hydrogeology 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 Dolomite. The origin of the Lockport Dolomite is tidal reefs deposited in warm, high-energy shallow seas. Overlying the Lockport Dolomite are rocks of the Silurian Tymochtee and Greenfield Dolomites, which were also deposited in warm, shallow seas.

Silurian-age limestones and dolomites (collectively called carbonates) are the uppermost bedrock formation in the southeastern corner of Henry County. Known as the Salina Group, these carbonate rocks were deposited in tidal flats associated with warm, shallow seas. They 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.

Lower Mississippian and Upper Devonian Sunbury and Bedford shales (Slucher et al., 2006) and Devonian-age Antrim Shale (ODNR, Division of Soil and Water Resources, Bedrock State Aquifer Map, 2000 and Slucher et al., 2006) underlie the northwestern third of Henry County. These thick, dark brown to black (except for the Bedford, which is gray to olive green) 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 or Formation	Description
Lower Mississippian and Upper Devonian	Sunbury and Bedford Shales, undivided *MDs*	Sunbury Shale is brownish black to greenish black, carbonaceous and pyritic. Bedford Shale is gray to olive green, silty and clayey. Poor source of ground water.
Devonian	Antrim Shale *Da*	Brownish black carbonaceous shale. Poor source of ground water.
	Ten Mile Creek Dolomite and Silica Formation, undivided *Dts*	Ten Mile Creek Dolomite is gray, thin- to medium-bedded, contains some chert nodules. Silica Formation consists of a bluish gray, fossiliferous clayey shale and limestone.
	Dundee Limestone *Ddu*	Thin- to massive-bedded limestone, can be blue, gray or brown in color, upper part very fossiliferous, lower part contains cherty dolomite.
	Detroit River Group Lucas Dolomite Amherstburg Dolomite Sylvania Sandstone *Ddr*	Lucas and Amherstburg Dolomites are brown to gray in color and medium - to thick-bedded. Sylvania Sandstone is white, fine-grained, and locally dolomitic.
Silurian	Salina Group *Ss*	Predominantly gray to brown dolomite, thin- to medium-bedded. Locally includes shale, anhydrite, and/or gypsum beds.
	Tymochtee and Greenfield Dolomites, undivided *Stg*	Tymochtee Dolomite is gray and brown in color, finely crystalline, thin- to massive-bedded with carbonaceous shale laminae and beds. Greenfield Dolomite is gray and brown in color, finely to coarsely crystalline, argillaceous, and occurs as massive beds to laminae.
	Lockport Dolomite *Sl*	White to gray dolomite, finely to coarsely crystalline, medium- to massive-bedded, fossiliferous, and vuggy.

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.

Deep, larger diameter wells drilled into the Salina Group can produce yields exceeding 100 gpm (ODNR, Division of Soil and Water Resources, Open File, Bedrock State Aquifer Map, 2000, ODNR, Division of Water, 1970, Palombo, 1983, Schmidt, 1982, and Miller, 1997). The Lockport Dolomite extends across the southeastern half of the county at depth. Yields for the Silurian Tymochtee and Greenfield Dolomites vary from 5 to 25 gpm up to 25 to 100 gpm from these relatively deep aquifers (ODNR, Division of Soil and Water Resources, Open File, Bedrock State Aquifer Map, 2000). Along the eastern edge of the county, the Salina Group produces yields of 25 to 100 gpm to greater than 100 gpm (ODNR, Division of Soil and Water Resources, Open File, Bedrock State Aquifer Map, 2000, and Schmidt, 1982). The Salina Group is the uppermost aquifer in the southeastern corner, but underlies the undivided Ten Mile Creek Dolomite and Silica Formation in northeastern Henry County. Yields from the Detroit River Group, Dundee Limestone, and the Ten Mile Creek Dolomite and Silica Formation are moderate, ranging from 5 to 25 gpm up to 25 to 100 gpm (ODNR, Division of Soil and Water Resources, Open File, Bedrock State Aquifer Map, 2000, ODNR, Division 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, Division of Soil and Water Resources, Open File, Bedrock State Aquifer Map, 2000). Water underlying the shale tends to be very high in sulfur, hydrogen sulfide, and iron.

The Sunbury and Bedford Shales, undivided, and the Antrim Shale in northwestern Henry County are poor sources of ground water. Yields are usually 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 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, Division of Soil and Water Resources, 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. (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 screen 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 because 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, Division of Soil and Water Resources, 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 is likely 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 effective 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.

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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 Soil and Water Resources. 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 at which water was encountered 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 Openings 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 7 Fd-Wave-eroded Lake Plain setting in the eastern half of the county. Depths of 30 to 50 feet (5) were utilized for the 7 Fd-Wave-eroded Lake Plain in the western half 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 7 Fd-Wave-eroded Lake Plain 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 7 F-Glacial Lake Plains Deposits and 7 Fd-Wave-eroded Lake Plain 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, Division 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 Soil and 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 Soil and Water Resources 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). Limestone was evaluated as the aquifer in the 7Fd-Wave-eroded Lake Plain 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 similarly 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 Henry 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
Vaughnsville	deltaic	5	loam
Wabasha	fine alluvium	7	shrink/swell clay
Warners	depression	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, Division 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 Soil and Water Resources, 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 Soil and Water Resources 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 & Gravel w/Silt & 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 & Gravel w/Silt & 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 & Gravel w/Silt & 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 clayey lacustrine sediments. Silt and Clay with Till with a rating of (4) was used in areas where the lacustrine and till deposits have been wave-planed. Silt and Clay with Till with a rating of (3) was used for areas with thicker sequences of 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, Division 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 Soil and Water Resources, 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 Soil and Water Resources 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/ft^2). This rating reflects the overall fine-grained nature of these sands and the presence of fines.

Limestone aquifers with an aquifer media rating of (7) or (8) were assigned a hydraulic conductivity rating of 300-700 gpd/ft^2 (4). These rocks are rated as the uppermost aquifer in the southern half of the county. All of the shale aquifers in northwestern Henry County were assigned a hydraulic conductivity rating of 1-100 gpd/ft^2 (1).

APPENDIX B

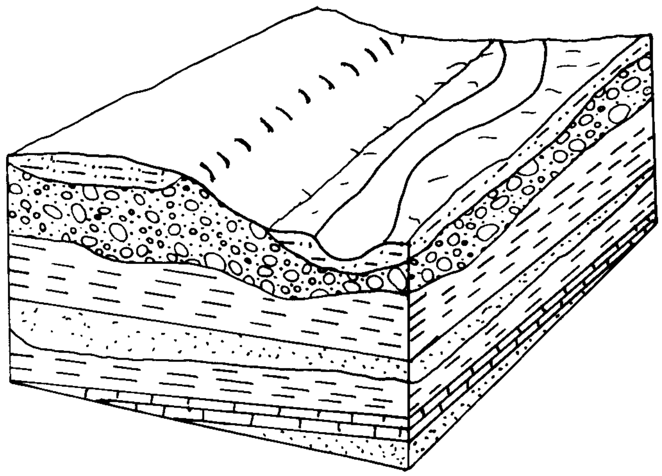
DESCRIPTION OF HYDROGEOLOGIC SETTINGS AND CHARTS

Ground water pollution potential mapping in Henry County resulted in the identification of eight hydrogeologic settings within the Glaciated Central Region. The list of these settings, the range of pollution potential index calculations, and the number of index calculations for each setting are provided in Table 12. Pollution potential indexes computed for Henry 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
7Ea - Rver alluvium with Overbank Deposits	95 - 151	36
7Eb - River Alluvium without Overbank Deposits	148	1
7Ec - Alluvium over Sedimentary Rock	140	1
7Ed - Alluvium over Glacial Till	158	1
7F - Glacial Lake Plains Deposits	86 - 149	59
7Fd – Wave-eroded Lake Plain	67-142	58
7H - Beaches, Beach Ridge, and Sand Dunes	94 - 173	32
7I - Marshes and Swamps	173	1

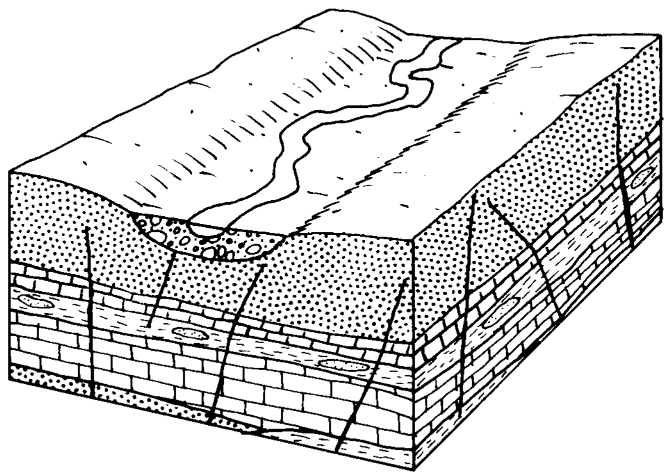
The following information provides a description of each hydrogeologic setting identified in the county, a block diagram illustrating the characteristics of the setting, and a listing of the charts for each unique combination of pollution potential indexes calculated for each setting. The charts provide 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.



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.

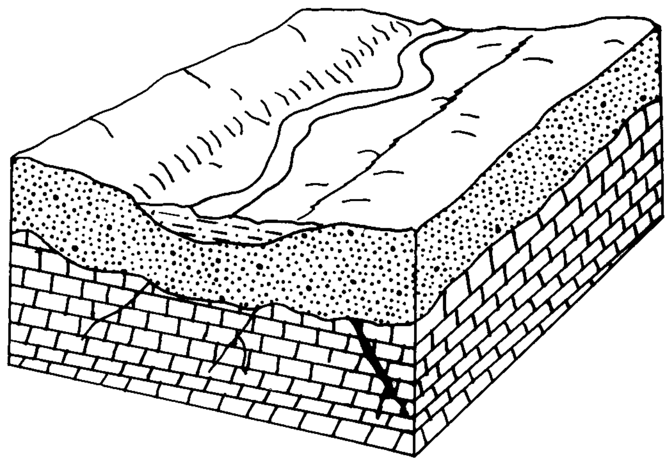
GWPP index values for the hydrogeologic setting of River Alluvium with Overbank Deposits range from 95 to 151 with the total number of GWPP index calculations equaling 36.



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.

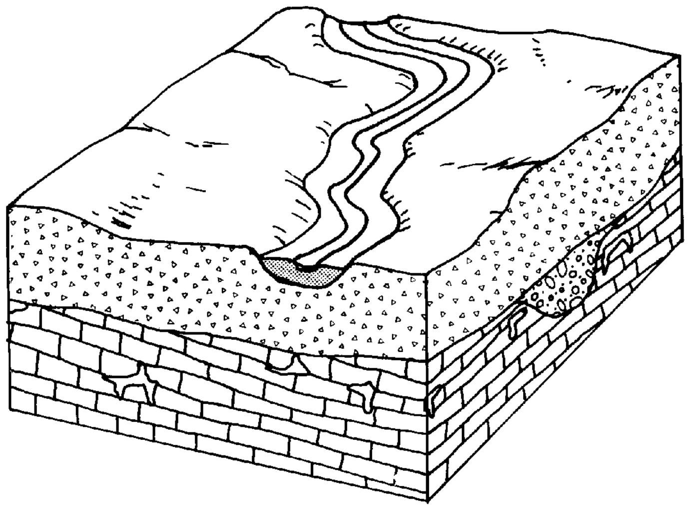
The GWPP index value for the hydrogeologic setting of River Alluvium without Overbank Deposits is 148 with the total number of GWPP index calculations equaling 1.



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.

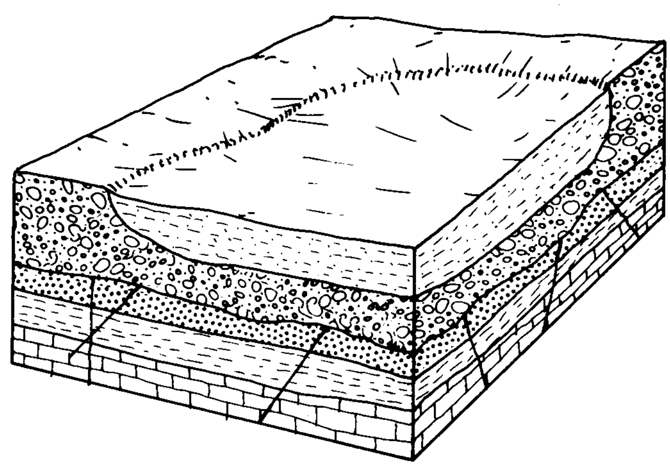
The GWPP index value for the hydrogeologic setting Alluvium over Sedimentary Rocks is 140 with the total number of GWPP index calculations equaling 1.



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.

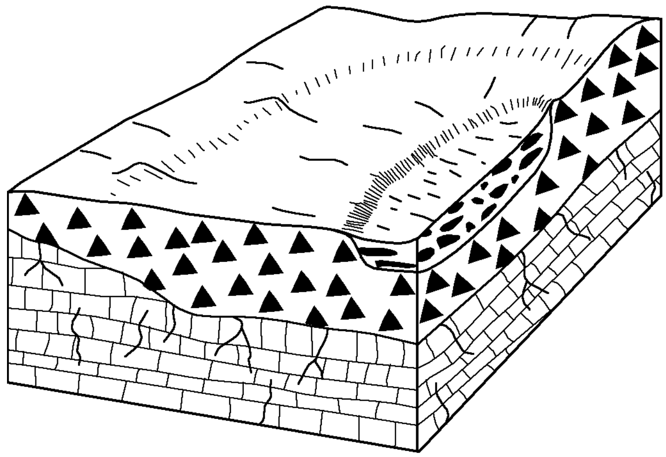
The GWPP index value for the hydrogeologic setting Alluvium Over Glacial Till is 158 with the total number of GWPP index calculations equaling 1.



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.

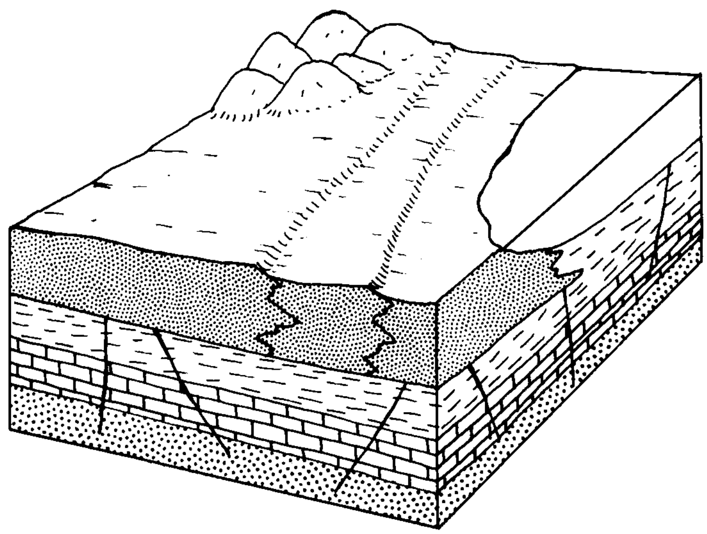
GWPP index values for the hydrogeologic setting of Glacial Lake Plains Deposits range from 86 to 149 with the total number of GWPP index calculations equaling 59.



7Fd-Wave-eroded Lake Plain

This hydrogeologic setting is characterized by very flat-lying topography caused by wave-erosion of glacial Lake Maumee. The setting consists of thin, patchy silty to clayey lacustrine deposits and wave-eroded, "water-modified" till. Surficial drainage is typically very poor; ponding is very common after rains. This setting occupies the northwest corner and south central and southeastern portions of the county. The vadose zone media consists of very thin silty to clayey lacustrine sediments that overlie clayey glacial till. In some areas, the clayey glacial till is at the surface. This setting is similar to the 7F-Glacial Lake Plain Deposits setting except that waves have eroded away all or most of the fine-grained lacustrine sediments overlying the glacial till. The aquifer consists of the underlying limestone or shale bedrock, or thin layers of sand and gravel in the till. Maximum ground water yields greater than 100 gpm are possible from the Silurian Lockport, Tymochtee, Greenfield and Salina Groups. Depth to water is commonly shallow. Soils are shrink-swell (non-aggregated) clay derived from clayey lacustrine sediments and clayey till. Recharge in this setting is moderately low due to the relatively low permeability soils and vadose zone material and the relatively shallow depth to the water table and bedrock aquifer.

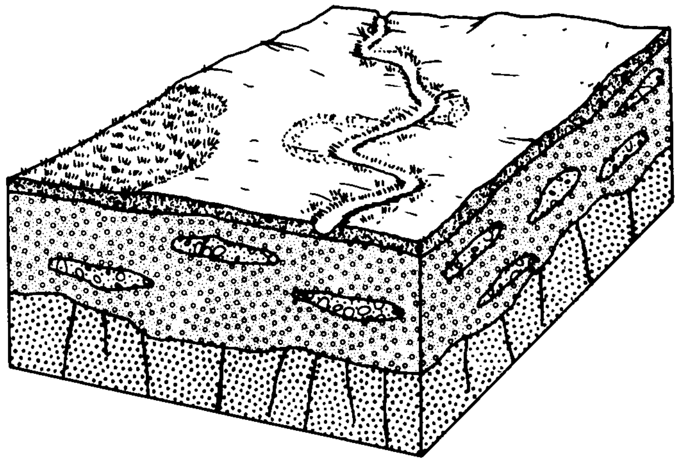
GWPP index values for the hydrogeologic setting of Wave-eroded Lake Plain range from 67 to 142, with the total number of GWPP index calculations equaling 58.



<u>7H-Beaches, Beach Ridge, and Sand Dunes</u>

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.



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; depressional 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.

Table 13. Hydrogeologic Settings, DRASTIC Factors, and Ratings

Setting	Depth to water (ft.)	Recharge (in./yr.)	Aquifer Media	Soil Media	Topography (% slope)	Vadose Zone Media	Hydraulic Conductivity	Rating	Pesticide Rating_
7Ea01	15-30	4-7	Massive Shale	Shrink/Swell Clay	2-6	Sand & Gravel w/Silt & Clay	1-100	116	149
7Ea02	15-30	4-7	Massive Shale	Shrink/Swell Clay	0-2	Sand & Gravel w/Silt & Clay	1-100	117	152
7Ea03	30-50	4-7	Massive Shale	Silty Loam	2-6	Silt and Clay	1-100	95	120
7Ea04	15-30	4-7	Sand & Gravel	Shrink/Swell Clay	2-6	Sand & Gravel w/Silt & Clay	100-300	128	160
7Ea05	15-30	4-7	Sand & Gravel	Silty Loam	0-2	Sand & Gravel w/Silt & Clay	100-300	126	151
7Ea06	15-30	4-7	Massive Shale	Sandy Loam	2-6	Sand & Gravel w/Silt & Clay	1-100	114	144
7Ea07	30-50	4-7	Massive Shale	Silty Loam	2-6	Sand & Gravel w/Silt & Clay	1-100	100	124
7Ea08	15-30	4-7	Sand & Gravel	Sandy Loam	2-6	Sand & Gravel w/Silt & Clay	100-300	126	155
7Ea09	15-30	4-7	Sand & Gravel	Loam	0-2	Silt and Clay	100-300	120	149
7Ea10	5-15	4-7	Massive Shale	Loam	0-2	Sand & Gravel w/Silt & Clay	1-100	117	152
7Ea11	30-50	4-7	Massive Shale	Silty Loam	0-2	Silt and Clay	1-100	96	123
7Ea12	15-30	4-7	Massive Shale	Silty Loam	2-6	Silt and Clay	1-100	105	130
7Ea13	15-30	4-7	Massive Shale	Silty Loam	0-2	Silt and Clay	1-100	106	121
7Ea14	30-50	4-7	Massive Shale	Sandy Loam	0-2	Sand & Gravel w/Silt & Clay	1-100	105	137
7Ea15	15-30	4-7	Limestone	Silty Loam	0-2	Silt and Clay	300-700	133	157
7Ea16	0-5	7-10	Sand & Gravel	Loam	0-2	Sand & Gravel w/Silt & Clay	100-300	151	179
7Ea17	0-5	7-10	Sand & Gravel	Silty Loam	0-2	Sand & Gravel w/Silt & Clay	100-300	149	174
7Ea18	30-50	4-7	Massive Shale	Loam	2-6	Sand & Gravel w/Silt & Clay	1-100	102	129
7Ea19	15-30	7-10	Limestone	Loam	0-2	Sand & Gravel w/Silt & Clay	300-700	145	171
7Ea20	15-30	4-7	Limestone	Loam	2-6	Sand & Gravel w/Silt & Clay	300-700	136	160
7Ea21	15-30	4-7	Limestone	Silty Loam	0-2	Sand & Gravel w/Silt & Clay	300-700	135	158
7Ea22	15-30	4-7	Massive Shale	Clay Loam	2-6	Sand & Gravel w/Silt & Clay	1-100	108	129
7Ea23	15-30	4-7	Sand & Gravel	Loam	0-2	Sand & Gravel w/Silt & Clay	100-300	128	156
7Ea24	15-30	4-7	Limestone	Silty Loam	2-6	Sand & Gravel w/Silt & Clay	300-700	134	155

Setting	Depth to water (ft.)	Recharge (in./yr.)	Aquifer Media	Soil Media	Topography (% slope)	Vadose Zone Media	Hydraulic Conductivity	Rating	Pesticide Rating_
7Ea25	15-30	4-7	Massive Shale	Silty Loam	0-2	Sand & Gravel w/Silt & Clay	1-100	111	137
7Ea26	15-30	4-7	Sand & Gravel	Silty Loam	0-2	Silt and Clay	100-300	124	150
7Ea27	15-30	4-7	Massive Shale	Loam	2-6	Sand & Gravel w/Silt & Clay	1-100	112	139
7Ea28	15-30	4-7	Limestone	Loam	2-6	Silt and Clay	300-700	131	156
7Ea29	15-30	4-7	Massive Shale	Loam	0-2	Sand & Gravel w/Silt & Clay	1-100	113	142
7Ea30	5-15	4-7	Sand & Gravel	Clay Loam	0-2	Silt and Clay	100-300	126	149
7Ea31	15-30	4-7	Limestone	Loam	0-2	Silt and Clay	300-700	132	159
7Ea32	15-30	4-7	Sand & Gravel	Loam	0-2	Sand & Gravel w/Silt & Clay	100-300	125	153
7Ea33	5-15	4-7	Limestone	Silty Loam	0-2	Silt and Clay	300-700	140	164
7Ea34	5-15	4-7	Massive Shale	Loam	2-6	Sand & Gravel w/Silt & Clay	1-100	122	149
7Ea35	15-30	4-7	Sand & Gravel	Silty Loam	0-2	Sand & Gravel w/Silt & Clay	100-300	123	148
7Ea36	5-15	4-7	Limestone	Loam	0-2	Silt and Clay	300-700	142	169
7Eb1	5-15	4-7	Sand & Gravel	Gravel	0-2	Sand & Gravel w/Silt & Clay	100-300	148	191
7Ec1	5-15	4-7	Limestone	Silty Loam	0-2	Silt and Clay	300-700	140	164
7Ed1	5-15	7-10	Limestone	Silty Loam	0-2	Sand & Gravel w/Silt & Clay	300-700	158	180
7F01	30-50	4-7	Sand & Gravel	Sandy Loam	0-2	Sand & Gravel w/Silt & Clay	100-300	117	148
7F02	30-50	2-4	Massive Shale	Loam	0-2	Silt and Clay	1-100	86	116
7F03	15-30	2-4	Limestone	Clay Loam	0-2	Silt and Clay	300-700	116	137
7F04	15-30	2-4	Massive Shale	Loam	0-2	Silt and Clay	1-100	96	126
7F05	15-30	2-4	Massive Shale	Sandy Loam	2-6	Silt and Clay	1-100	97	128
7F06	15-30	2-4	Massive Shale	Sandy Loam	0-2	Silt and Clay	1-100	98	131
7F07	15-30	2-4	Massive Shale	Shrink/Swell Clay	2-6	Silt and Clay	1-100	99	133
7F08	30-50	2-4	Sand & Gravel	Sandy Loam	0-2	Silt and Clay	100-300	100	132
7F09	15-30	2-4	Massive Shale	Shrink/Swell Clay	0-2	Silt and Clay	1-100	100	136
7F10	15-30	2-4	Massive Shale	Clay Loam	0-2	Silt and Clay	1-100	92	116

Setting	Depth to water (ft.)	Recharge (in./yr.)	Aquifer Media	Soil Media	Topography (% slope)	Vadose Zone Media	Hydraulic Conductivity	Rating	Pesticide Rating_
7F11	30-50	4-7	Massive Shale	Sandy Loam	0-2	Sand & Gravel w/Silt & Clay	1-100	105	137
7F12	5-15	2-4	Massive Shale	Loam	0-2	Silt and Clay	1-100	106	136
7F13	30-50	2-4	Limestone	Sandy Loam	0-2	Silt and Clay	300-700	112	142
7F14	15-30	4-7	Massive Shale	Shrink/Swell Clay	0-2	Sand & Gravel w/Silt & Clay	1-100	117	152
7F15	15-30	4-7	Massive Shale	Shrink/Swell Clay	18+	Sand & Gravel w/Silt & Clay	1-100	108	125
7F16	30-50	2-4	Limestone	Shrink/Swell Clay	0-2	Silt and Clay	300-700	114	147
7F17	15-30	4-7	Massive Shale	Clay Loam	0-2	Sand & Gravel w/Silt & Clay	1-100	109	132
7F18	15-30	4-7	Massive Shale	Clay Loam	2-6	Sand & Gravel w/Silt & Clay	1-100	118	139
7F19	15-30	2-4	Sand & Gravel	Sandy Loam	0-2	Silt and Clay	100-300	110	142
7F20	5-15	2-4	Massive Shale	Shrink/Swell Clay	0-2	Silt and Clay	1-100	110	146
7F21	5-15	4-7	Sand & Gravel	Shrink/Swell Clay	2-6	Sand & Gravel w/Silt & Clay	100-300	141	173
7F22	15-30	2-4	Sand & Gravel	Shrink/Swell Clay	0-2	Silt and Clay	100-300	112	147
7F23	15-30	2-4	Limestone	Loam	2-6	Silt and Clay	300-700	119	144
7F24	15-30	4-7	Massive Shale	Loam	0-2	Sand & Gravel w/Silt & Clay	1-100	113	142
7F25	15-30	2-4	Massive Shale	Clay Loam	2-6	Silt and Clay	1-100	91	113
7F26	5-15	2-4	Limestone	Clay Loam	6-12	Silt and Clay	300-700	121	132
7F27	5-15	4-7	Sand & Gravel	Sandy Loam	0-2	Sand & Gravel w/Silt & Clay	100-300	140	171
7F28	15-30	4-7	Massive Shale	Sandy Loam	0-2	Sand & Gravel w/Silt & Clay	1-100	115	147
7F29	15-30	4-7	Massive Shale	Shrink/Swell Clay	2-6	Sand & Gravel w/Silt & Clay	1-100	116	149
7F30	15-30	4-7	Massive Shale	Shrink/Swell Clay	2-6	Sand & Gravel w/Silt & Clay	1-100	116	149
7F31	15-30	2-4	Limestone	Shrink/Swell Clay	2-6	Silt and Clay	300-700	123	154
7F32	15-30	4-7	Massive Shale	Shrink/Swell Clay	0-2	Sand & Gravel w/Silt & Clay	1-100	117	152
7F33	15-30	4-7	Sand & Gravel	Shrink/Swell Clay	0-2	Silt and Clay	100-300	130	165
7F34	15-30	4-7	Limestone	Sandy Loam	0-2	Sand & Gravel w/Silt & Clay	300-700	139	168
7F35	15-30	2-4	Limestone	Shrink/Swell Clay	2-6	Sand & Gravel w/Silt & Clay	300-700	128	158
7F36	5-15	4-7	Limestone	Sandy Loam	0-2	Sand & Gravel w/Silt & Clay	300-700	149	178

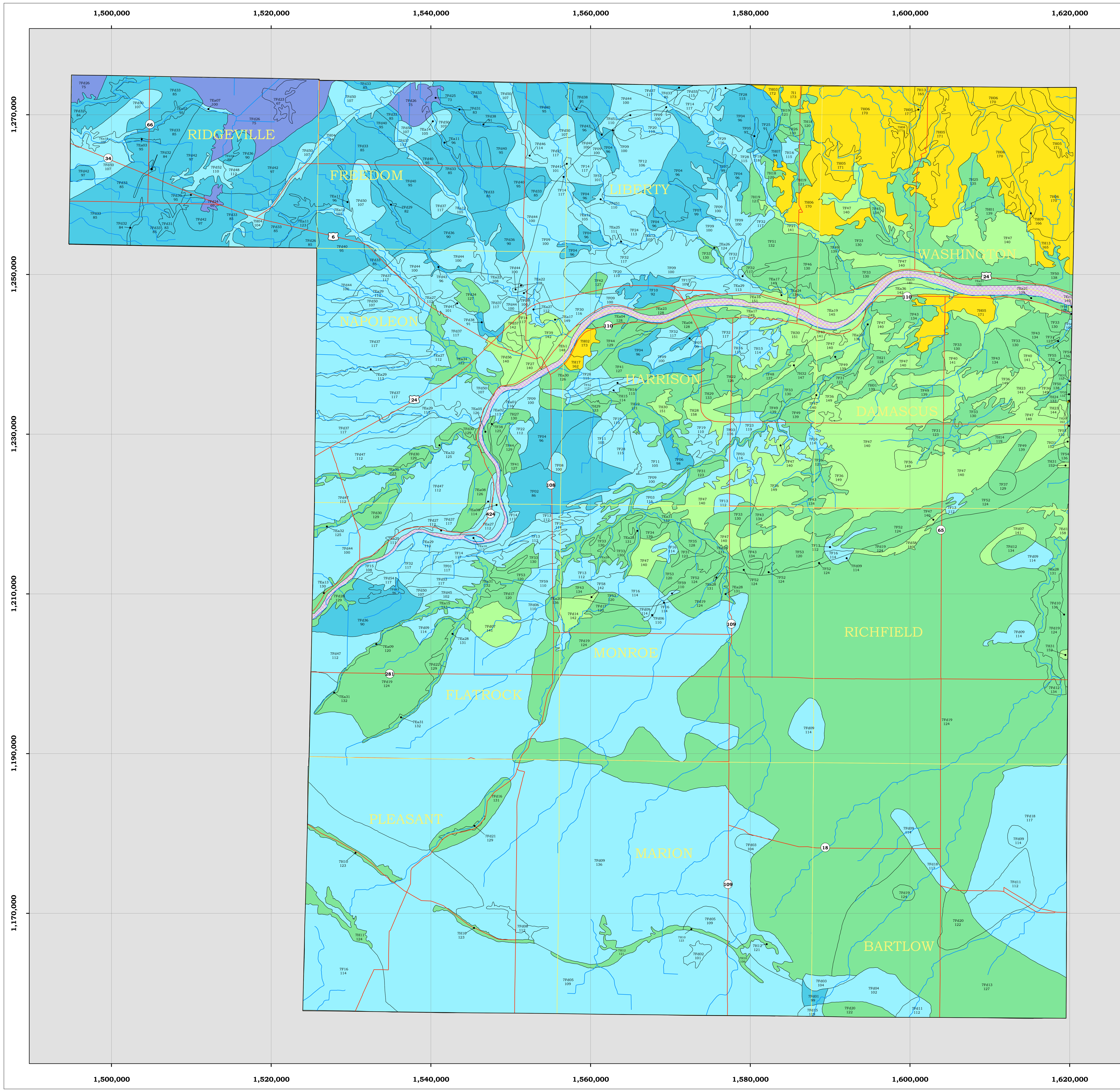
Setting	Depth to water (ft.)	Recharge (in./yr.)	Aquifer Media	Soil Media	Topography (% slope)	Vadose Zone Media	Hydraulic Conductivity	Rating	Pesticide Rating_
7F37	30-50	4-7	Limestone	Sandy Loam	0-2	Sand & Gravel w/Silt & Clay	300-700	129	158
7F38	15-30	4-7	Sand & Gravel	Silty Loam	2-6	Sand & Gravel w/Silt & Clay	100-300	125	148
7F39	5-15	4-7	Sand & Gravel	Shrink/Swell Clay	0-2	Sand & Gravel w/Silt & Clay	100-300	142	176
7F40	15-30	4-7	Limestone	Shrink/Swell Clay	0-2	Sand & Gravel w/Silt & Clay	300-700	141	173
7F40	15-30	4-7	Limestone	Shrink/Swell Clay	0-2	Sand & Gravel w/Silt & Clay	300-700	141	173
7F41	15-30	4-7	Sand & Gravel	Sandy Loam	0-2	Sand & Gravel w/Silt & Clay	100-300	127	158
7F42	5-15	4-7	Massive Shale	Shrink/Swell Clay	0-2	Sand & Gravel w/Silt & Clay	1-100	127	162
7F43	5-15	2-4	Limestone	Shrink/Swell Clay	0-2	Silt and Clay	300-700	134	167
7F44	15-30	4-7	Sand & Gravel	Shrink/Swell Clay	0-2	Sand & Gravel w/Silt & Clay	100-300	129	163
7F45	15-30	4-7	Limestone	Shrink/Swell Clay	6-12	Sand & Gravel w/Silt & Clay	300-700	134	158
7F46	15-30	4-7	Sand & Gravel	Sandy Loam	0-2	Sand & Gravel w/Silt & Clay	100-300	130	161
7F47	15-30	4-7	Limestone	Shrink/Swell Clay	2-6	Sand & Gravel w/Silt & Clay	300-700	140	170
7F48	15-30	4-7	Limestone	Loam	0-2	Sand & Gravel w/Silt & Clay	300-700	137	163
7F49	15-30	4-7	Limestone	Sandy Loam	0-2	Sand & Gravel w/Silt & Clay	300-700	139	168
7F50	15-30	4-7	Limestone	Sandy Loam	2-6	Sand & Gravel w/Silt & Clay	300-700	138	165
7F51	15-30	4-7	Sand & Gravel	Shrink/Swell Clay	0-2	Sand & Gravel w/Silt & Clay	100-300	132	166
7F52	15-30	2-4	Limestone	Shrink/Swell Clay	0-2	Silt and Clay	300-700	124	157
7F53	15-30	2-4	Limestone	Loam	0-2	Silt and Clay	300-700	120	147
7F54	15-30	4-7	Limestone	Shrink/Swell Clay	0-2	Silt and Clay	300-700	136	169
7F55	15-30	4-7	Limestone	Loam	0-2	Silt and Clay	300-700	132	159
7F56	15-30	2-4	Limestone	Clay Loam	12-18	Silt and Clay	300-700	109	116
7F57	15-30	2-4	Massive Shale	Loam	0-2	Sand & Gravel w/Silt & Clay	1-100	101	130
7F58	5-15	4-7	Limestone	Loam	0-2	Silt and Clay	300-700	142	169
7F59	30-50	2-4	Limestone	Loam	0-2	Silt and Clay	300-700	110	137
7Fd01	50-75	2-4	Limestone	Shrink/Swell Clay	0-2	Silt and Clay w/till	300-700	99	133
7Fd02	30-50	2-4	Limestone	Clay Loam	0-2	Silt and Clay w/till	300-700	101	123

Setting	Depth to water (ft.)	Recharge (in./yr.)	Aquifer Media	Soil Media	Topography (% slope)	Vadose Zone Media	Hydraulic Conductivity	Rating	Pesticide Rating_
7Fd03	50-75	2-4	Limestone	Shrink/Swell Clay	0-2	Silt and Clay w/till	300-700	104	137
7Fd04	50-75	2-4	Limestone	Shrink/Swell Clay	0-2	Silt and Clay w/till	300-700	102	136
7Fd05	30-50	2-4	Limestone	Shrink/Swell Clay	0-2	Silt and Clay w/till	300-700	109	143
7Fd06	30-50	2-4	Limestone	Loam	0-2	Silt and Clay w/till	300-700	110	137
7Fd07	15-30	4-7	Limestone	Shrink/Swell Clay	0-2	Sand & Gravel w/Silt & Clay	300-700	141	173
7Fd08	30-50	2-4	Limestone	Sandy Loam	0-2	Silt and Clay w/till	300-700	112	142
7Fd09	30-50	2-4	Limestone	Shrink/Swell Clay	0-2	Silt and Clay w/till	300-700	114	147
7Fd10	15-30	4-7	Limestone	Shrink/Swell Clay	0-2	Silt and Clay w/till	300-700	136	169
7Fd11	30-50	2-4	Limestone	Shrink/Swell Clay	0-2	Silt and Clay w/till	300-700	112	146
7Fd12	5-15	2-4	Limestone	Shrink/Swell Clay	0-2	Silt and Clay w/till	300-700	134	167
7Fd13	15-30	2-4	Limestone	Shrink/Swell Clay	0-2	Silt and Clay w/till	300-700	127	127
7Fd14	5-15	4-7	Limestone	Loam	0-2	Silt and Clay w/till	300-700	142	169
7Fd15	15-30	2-4	Limestone	Shrink/Swell Clay	0-2	Silt and Clay w/till	300-700	119	153
7Fd16	30-50	4-7	Limestone	Shrink/Swell Clay	0-2	Sand & Gravel w/Silt & Clay	300-700	131	163
7Fd17	15-30	2-4	Limestone	Loam	0-2	Silt and Clay w/till	300-700	120	147
7Fd18	30-50	2-4	Limestone	Shrink/Swell Clay	0-2	Silt and Clay w/till	300-700	117	150
7Fd19	15-30	2-4	Limestone	Shrink/Swell Clay	0-2	Silt and Clay w/till	300-700	124	157
7Fd20	15-30	2-4	Limestone	Shrink/Swell Clay	0-2	Silt and Clay w/yill	300-700	122	156
7Fd21	30-50	4-7	Limestone	Sandy Loam	0-2	Sand & Gravel w/Silt & Clay	300-700	129	158
7Fd22	15-30	2-4	Limestone	Shrink/Swell Clay	0-2	Sand & Gravel w/Silt & Clay	300-700	129	161
7Fd23	50-75	2-4	Massive Shale	Clay Loam	0-2	Silt and Clay w/till	1-100	67	92
7Fd24	50-75	2-4	Massive Shale	Silty Loam	0-2	Silt and Clay w/till	1-100	69	97
7Fd25	50-75	2-4	Massive Shale	Sandy Loam	0-2	Silt and Clay w/till	1-100	73	107
7Fd26	50-75	2-4	Massive Shale	Shrink/Swell Clay	0-2	Silt and Clay w/till	1-100	75	112
7Fd27	15-30	4-7	Massive Shale	Shrink/Swell Clay	0-2	Silt and Clay w/till	1-100	112	148

Setting	Depth to water (ft.)	Recharge (in./yr.)	Aquifer Media	Soil Media	Topography (% slope)	Vadose Zone Media	Hydraulic Conductivity	Rating	Pesticide Rating_
7Fd28	15-30	4-7	Massive Shale	Shrink/Swell Clay	12-18	Silt and Clay w/till	1-100	105	129
7Fd29	30-50	2-4	Massive Shale	Sandy Loam	2-6	Silt and Clay w/till	1-100	82	114
7Fd30	15-30	4-7	Sand & Gravel	Shrink/Swell Clay	0-2	Sand & Gravel w/Silt & Clay	100-300	129	163
7Fd31	30-50	2-4	Massive Shale	Sandy Loam	0-2	Silt and Clay w/till	1-100	83	117
7Fd32	30-50	2-4	Massive Shale	Shrink/Swell Clay	2-6	Silt and Clay w/till	1-100	84	119
7Fd33	30-50	2-4	Massive Shale	Shrink/Swell Clay	0-2	Silt and Clay w/till	1-100	85	122
7Fd34	5-15	4-7	Massive Shale	Shrink/Swell Clay	0-2	Sand & Gravel w/Silt & Clay	1-100	127	162
7Fd35	50-75	2-4	Sand & Gravel	Sandy Loam	0-2	Silt and Clay w/till	100-300	88	121
7Fd36	50-75	2-4	Sand & Gravel	Shrink/Swell Clay	0-2	Silt and Clay w/till	100-300	90	126
7Fd37	15-30	4-7	Massive Shale	Shrink/Swell Clay	0-2	Sand & Gravel w/Silt & Clay	1-100	117	152
7Fd38	15-30	2-4	Massive Shale	Loam	0-2	Silt and Clay w/till	1-100	91	122
7Fd39	50-75	4-7	Massive Shale	Sandy Loam	0-2	Sand & Gravel w/Silt & Clay	1-100	95	127
7Fd40	15-30	2-4	Massive Shale	Shrink/Swell Clay	0-2	Silt and Clay w/till	1-100	95	132
7Fd41	15-30	2-4	Massive Shale	Loam	0-2	Sand & Gravel w/Silt & Clay	1-100	101	130
7Fd42	50-75	4-7	Massive Shale	Shrink/Swell Clay	0-2	Sand & Gravel w/Silt & Clay	1-100	97	132
7Fd43	15-30	2-4	Massive Shale	Loam	0-2	Silt and Clay w/till	1-100	96	126
7Fd44	15-30	2-4	Massive Shale	Shrink/Swell Clay	0-2	Silt and Clay w/till	1-100	100	136
7Fd45	30-50	2-4	Sand & Gravel	Shrink/Swell Clay	0-2	Silt and Clay w/till	100-300	102	137
7Fd46	15-30	4-7	Massive Shale	Sandy Loam	2-6	Sand & Gravel w/Silt & Clay	1-100	114	144
7Fd47	15-30	2-4	Sand & Gravel	Shrink/Swell Clay	0-2	Silt and Clay w/till	100-300	112	147
7Fd48	50-75	4-7	Sand & Gravel	Shrink/Swell Clay	0-2	Sand & Gravel w/Silt & Clay	100-300	112	146
7Fd49	30-50	4-7	Massive Shale	Shrink/Swell Clay	2-6	Sand & Gravel w/Silt & Clay	1-100	106	139
7Fd50	30-50	4-7	Massive Shale	Shrink/Swell Clay	0-2	Sand & Gravel w/Silt & Clay	1-100	107	142
7Fd51	5-15	2-4	Massive Shale	Shrink/Swell Clay	0-2	Silt and Clay w/till	1-100	110	146
7Fd52	50-75	4-7	Sand & Gravel	Sandy Loam	0-2	Sand & Gravel w/Silt & Clay	100-300	110	141

Setting	Depth to water (ft.)	Recharge (in./yr.)	Aquifer Media	Soil Media	Topography (% slope)	Vadose Zone Media	Hydraulic Conductivity	Rating	Pesticide Rating_
7Fd53	30-50	4-7	Sand & Gravel	Sandy Loam	0-2	Sand & Gravel w/Silt & Clay	100-300	117	148
7Fd54	15-30	4-7	Massive Shale	Shrink/Swell Clay	0-2	Sand & Gravel w/Silt & Clay	1-100	117	152
7Fd55	15-30	4-7	Massive Shale	Sandy Loam	0-2	Sand & Gravel w/Silt & Clay	1-100	115	147
7Fd56	5-15	4-7	Sand and Gravel	Sandy Loam	0-2	Sand & Gravel w/Silt & Clay	100-300	140	171
7Fd57	5-15	4-7	Sand & Gravel	Shrink/Swell Clay	0-2	Sand & Gravel w/Silt & Clay	100-300	142	176
7Fd58	15-30	4-7	Limestone	Shrink/Swell Clay	2-6	Sand & Gravel w/Silt & Clay	300-700	140	170
7H01	15-30	4-7	Limestone	Sandy Loam	0-2	Sand & Gravel w/Silt & Clay	300-700	139	168
7H02	5-15	10+	Sand & Gravel	Gravel	0-2	Sand & Gravel w/Silt & Clay	100-300	173	214
7H03	5-15	10+	Sand & Gravel	Gravel	2-6	Sand & Gravel w/Silt & Clay	100-300	172	211
7H04	30-50	4-7	Massive Shale	Sandy Loam	2-6	Sand & Gravel w/Silt & Clay	1-100	104	134
7H05	5-15	10+	Sand & Gravel	Sand	0-2	Sand & Gravel w/Silt & Clay	100-300	171	209
7H06	5-15	10+	Sand & Gravel	Sand	2-6	Sand & Gravel w/Silt & Clay	100-300	170	206
7H07	30-50	2-4	Massive Shale	Sand	0-2	Silt and Clay	1-100	94	136
7H08	5-15	10+	Sand &Gravel	Sand	0-2	Sand & Gravel w/Silt & Clay	100-300	171	209
7H09	5-15	10+	Sand & Gravel	Sand	6-12	Sand & Gravel w/Silt & Clay	100-300	166	194
7H10	30-50	2-4	Limestone	Sandy Loam	2-6	Silt and Clay	300-700	106	135
7H11	30-50	2-4	Limestone	Sandy Loam	0-2	Silt and Clay	300-700	107	138
7H12	30-50	2-4	Limestone	Sandy Loam	2-6	Silt and Clay	300-700	111	139
7H13	5-15	10+	Sand & Gravel	Sandy Loam	0-2	Sand & Gravel w/Silt & Clay	100-300	165	194
7H14	15-30	2-4	Limestone	Loam	2-6	Silt and Clay	300-700	119	144
7H15	15-30	4-7	Massive Shale	Sandy Loam	2-6	Sand & Gravel w/Silt & Clay	1-100	114	144
7H16	15-30	4-7	Massive Shale	Sandy Loam	0-2	Sand & Gravel w/Silt & Clay	1-100	115	147
7H17	5-15	10+	Sand & Gravel	Loam	2-6	Sand & Gravel w/Silt & Clay	100-300	162	186
7H18	15-30	4-7	Massive Shale	Sand	2-6	Sand & Gravel w/Silt & Clay	1-100	120	159
7H19	15-30	4-7	Massive Shale	Sand	0-2	Sand & Gravel w/Silt & Clay	1-100	121	162
7H20	15-30	7-10	Limestone	Sand	0-2	Sand & Gravel w/Silt & Clay	300-700	163	199

Setting	Depth to water (ft.)	Recharge (in./yr.)	Aquifer Media	Soil Media	Topography (% slope)	Vadose Zone Media	Hydraulic Conductivity	Rating	Pesticide Rating_
7H21	30-50	4-7	Limestone	Sandy Loam	2-6	Sand & Gravel w/Silt & Clay	300-700	128	155
7H22	15-30	4-7	Sand & Gravel	Sandy Loam	2-6	Sand & Gravel w/Silt & Clay	100-300	126	155
7H23	5-15	4-7	Limestone	Sandy Loam	0-2	Silt and Clay	300-700	144	174
7H24	15-30	4-7	Limestone	Sandy Loam	2-6	Silt and Clay	300-700	133	161
7H25	30-50	4-7	Limestone	Sand	0-2	Sand & Gravel w/Silt & Clay	300-700	135	173
7H26	5-15	4-7	Massive Shale	Sand	2-6	Sand & Gravel w/Silt & Clay	1-100	130	169
7H27	15-30	4-7	Sand & Gravel	Sandy Loam	0-2	Sand & Gravel w/Silt & Clay	100-300	130	161
7H28	15-30	7-10	Limestone	Sand	0-2	Sand & Gravel w/Silt & Clay	300-700	158	195
7H29	15-30	7-10	Massive Shale	Sand	2-6	Sand & Gravel w/Silt & Clay	1-100	133	171
7H30	15-30	7-10	Sand & Gravel	Sand	2-6	Sand & Gravel w/Silt & Clay	100-300	151	188
7H31	15-30	7-10	Limestone	Sandy Loam	0-2	Sand & Gravel w/Silt & Clay	300-700	152	180
7H32	15-30	7-10	Sand & Gravel	Sand	6-12	Sand & Gravel w/Silt & Clay	100-300	147	176
7I1	5-15	10+	Sand & Gravel	Gravel	0-2	Sand & Gravel w/Silt & Clay	100-300	173	214



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
Miles
0 1 2 3 4 5 6
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
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Cartography by Robert Baker