GROUND WATER POLLUTION POTENTIAL
OF FULTON COUNTY, OHIO

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ABSTRACT

A groundwater pollution potential map of Fulton 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 Fulton County resulted in a map with symbols and colors, which illustrate areas of varying ground water pollution potential indexes ranging from 40 to 189.

Fulton County lies entirely within the Glaciated Central hydrogeologic setting. Limestones and dolomites of the Devonian System compose the aquifer in the southeastern corner of the county. Yields in the carbonate aquifers range from 5 to 25 gallons per minute (gpm) to 25 to 100 gpm. Shales of the Devonian and Mississippian Systems comprise the aquifer in the northeastern corner 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 Fulton 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 4400 of these wells exist in Fulton 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 Fulton County has been prepared to assist planners, managers, and state and local officials in evaluating the relative vulnerability of areas to ground water contamination from various sources of pollution. This information can be used to help direct resources and land use activities to appropriate areas, or to assist in protection, monitoring, and clean-up efforts.

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

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

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

Individuals in the county who are familiar with specific land use and management problems will recognize other beneficial uses of the pollution potential maps. Planning commissions and zoning boards can use these maps to help make informed decisions about the development of areas within their jurisdiction. Developers proposing projects within ground water sensitive areas may be required to show how ground water will be protected.

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

SUMMARY OF THE DRASTIC MAPPING PROCESS

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

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

The application of DRASTIC to an area requires the recognition of a set of assumptions made in the development of the system. DRASTIC evaluates the pollution potential of an area under the assumption that a contaminant with the mobility of water is introduced at the surface and flushed into the ground water by precipitation. Most important, DRASTIC cannot be applied to areas smaller than 100 acres in size and is not intended or designed to replace site-specific investigations.

Hydrogeologic Settings and Factors

To facilitate the designation of mappable units, the DRASTIC system used the framework of an existing classification system developed by Heath (1984), which divides the United States into 15 ground water regions based on the factors in a ground water system that affect occurrence and availability.

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

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

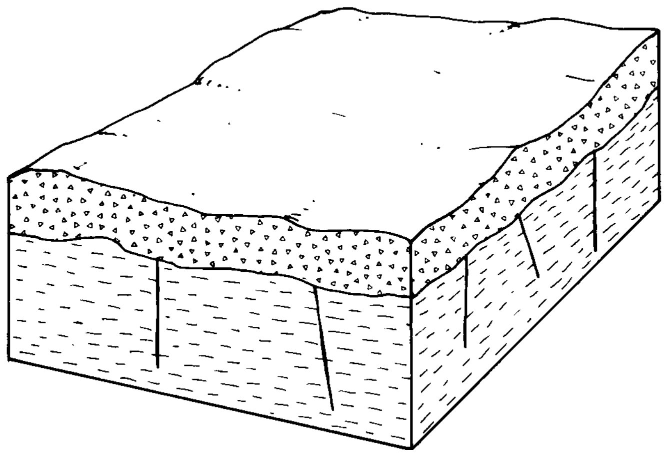
- **D** – Depth to Water
- **R** – Net Recharge
- **A** – Aquifer Media
- **S** – Soil Media
- **T** – Topography
- **I** – Impact of the Vadose Zone Media
- **C** – Conductivity (Hydraulic) of the Aquifer

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

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

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

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



7Ae-Glacial Till over Shale

This hydrogeologic setting is common in to the northeastern and southwestern corners of Fulton County. The area is characterized by flat-lying topography and very low relief. The vadose zone is composed of loamy to clayey glacial till and clayey to silty lacustrine deposits. The till and shale overlying the aquifer is thick and dense enough to be considered a confining layer in portions of northeastern Fulton County. The till and clayey lacustrine sediments may be fractured or jointed, particularly in areas where it is predominantly thin and weathered. Depth to water is typically great, moderate depths are found closer to tributary streams. Soils are generally shrink-swell (aggregated) clays. Areas adjacent to beach ridges have sand or sandy loam soils. The aquifer is usually fractured, massive black Devonian-age shale. In some areas, wells are completed in thin lenses of dirty, shale–rich gravel that directly overly the shale. Yields from the shale are typically less than 5 gpm and range from 5 to 25 gpm for the shaley gravel lenses. Recharge is generally low due to the thick and clayey vadose zone and soils are and the great depth to water.

GWPP index values for the hydrogeologic setting of Glacial Till over Shale range from 45 to 117 with the total number of GWPP index calculations equaling 32.

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

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

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

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

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

Weighting and Rating System

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

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

Pesticide DRASTIC

A special version of DRASTIC was developed to be used where the application of pesticides is a concern. The weights assigned to the DRASTIC factors were changed to reflect the processes that affect pesticide movement into the subsurface with particular emphasis on soils. Where other agricultural practices, such as the application of fertilizers, are a concern, general DRASTIC should be used to evaluate relative vulnerability to contamination. The process for calculating the Pesticide DRASTIC index is identical to the process used for calculating the general DRASTIC index. However, general DRASTIC and Pesticide DRASTIC numbers should not be compared because the conceptual basis in factor weighting and evaluation differs significantly. Table 1 lists the weights used for general and pesticide DRASTIC.

TABLE 1. ASSIGNED WEIGHTS FOR DRASTIC FEATURES

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

TABLE 2. RANGES AND RATINGS FOR DEPTH TO WATER

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

TABLE 3. RANGES AND RATINGS FOR NET RECHARGE

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

TABLE 4. RANGES AND RATINGS FOR AQUIFER MEDIA

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

TABLE 5. RANGES AND RATINGS FOR SOIL MEDIA

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

TABLE 6. RANGES AND RATINGS FOR TOPOGRAPHY

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

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

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

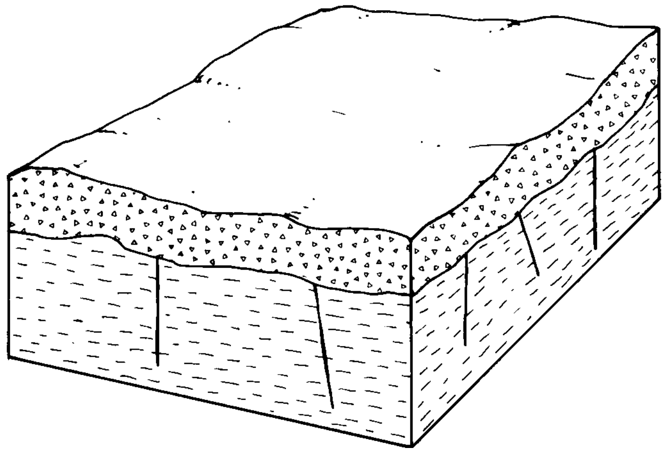
TABLE 8. RANGES AND RATINGS FOR HYDRAULIC CONDUCTIVITY

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

Integration of Hydrogeologic Settings and DRASTIC Factors

Figure 2 illustrates the hydrogeologic setting **7Ae1**, identified in mapping Henry County, and the pollution potential index calculated for the setting. Based on selected ratings for this setting, the pollution potential index is calculated to be **45**. 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 40 to **189**.

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



SETTING 7Ae1		GENERAL		
FEATURE	RANGE	WEIGHT	RATING	NUMBER
Depth to Water	100 +	5	1	5
Net Recharge	0 - 2	4	1	4
Aquifer Media	Massive Shale	3	2	6
Soil Media	Sandy Loam	2	6	12
Topography	0-2%	1	10	10
Impact of Vadose Zone	Confining Layer	5	1	5
Hydraulic Conductivity	1-100	3	1	3
		DRASTIC	INDEX	45

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

INTERPRETATION AND USE OF A GROUND WATER POLLUTION POTENTIAL MAP

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

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

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

Here the first number (**7**) refers to the major hydrogeologic region and the upper and lower case letters (**Ae**) refer to a specific hydrogeologic setting. The following number (**1**) references a certain set of DRASTIC parameters that are unique to this setting and are described in the corresponding setting chart. The second number (**45**) 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 FULTON COUNTY

Demographics

Fulton County occupies approximately 407 square miles in northwestern Ohio (Figure 3). Fulton County is bounded to the north by Lenawee County (Michigan), to the east by Lucas County, to the south by Henry County, and to the west by Williams County.

The approximate population of Fulton County, based upon 2000 estimates is 42,084 (Department of Development, Ohio County Profiles, 2002). Wauseon is the largest community and the county seat. Agriculture accounts for roughly 85 percent of the land usage in Fulton 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

Fulton County lies primarily within the Lake Plains section of the Central Till Plains Lowland Province (Frost, 1931; Fenneman, 1938, and Bier, 1956). Portions of northwestern and north central Fulton County lies within the Till Plains section of the Central Till Plains Lowland Province (Frost, 1931; Fenneman, 1938, and Bier, 1956). A flat lacustrine plain along with some subdued beach ridges and dunes characterizes most of Fulton County. North of Wauseon, the Defiance Moraine creates a subdued, hummocky ridge. In the northwestern corner of the county, the eastern margin of the Fort Wayne Moraine creates a subdued ridge that stands above the lake plain.

Climate

The Hydrologic Atlas for Ohio (Harstine, 1991) reports an average annual temperature of approximately 49 degrees Fahrenheit for Fulton County. The average temperatures increase slightly towards the south. Harstine (1991) shows that precipitation approximately averages 33 to 34 inches per year for the county, with precipitation increasing towards the northwest The mean annual precipitation for Wauseon is 34.7 inches per year based upon a thirty-year (1961-1980) period (Owenby and Ezell, 1992). The mean annual temperature at Wauseon for the same thirty-year period is 49.5 degrees Fahrenheit (Owenby and Ezell, 1992).

Figure 3. Location of Fulton County

Modern Drainage

The Maumee River and tributaries drain the southeast and south-central portions of Fulton County. The northeastern corner of the county is drained by Tenmile Creek. The area surrounding Lyons, in north-central Fulton County, drains to the north via the Raisin River into Michigan. The Defiance Moraine marks the east-west drainage divide north of Wauseon. South of the Defiance Moraine, the divide runs roughly southwestward between Wauseon and Archbold

Pre- and Inter-Glacial Drainage Changes

The drainage patterns of Fulton County have undergone relatively minor changes as a result of the multiple glaciations. Prior to glaciation, Fulton County was drained by a large, unnamed easterly-flowing tributary of the Napoleon River (Stout et al, 1943), Reimann (1979), and Plymale (1999). The Napoleon River is closely followed by the course of the modern Maumee River through Henry County Stout et al (1943). Reimann (1979) and Plymale (1999) discuss a roughly east-west trending buried valley that extends from Lyons to Fayette. It is unknown whether this valley corresponded to the unnamed tributary of the Napoleon River or if it was an ancestor of the Raisin River.

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. Table x summarizes the Pleistocene deposits found in Fulton County. Older ice advances that predate the most recent (Brunhes) magnetic reversal (about 730,000 Y.B.P.) are now commonly referred to as pre-Illinoian (formerly Kansan). Goldthwait et al, (1961) and Pavey et al, (1999) report that the late Wisconsinan Ice Sheet deposited the surficial till in Fulton County. Evidence for the earlier glaciations is lacking or obscured.

Reimann (1979) and Plymale (1999) discuss the glacial deposits of Fulton 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 toward the southeast corner (ODNR, Division of Geological Survey, Open File Bedrock Topography and ODNR, Division of Water, Glacial State Aquifer Map)

Till is an unsorted, non-stratified (non-bedded), mixture of sand, gravel, silt, and clay deposited directly by the ice sheet. There are two main types or facies of glacial till. Lodgement till is "plastered-down" or "bulldozed" at the base of an actively moving ice sheet. Lodgement till tends to be relatively dense and compacted and pebbles typically are angular, broken, and have a preferred direction or orientation. "Hardpan" and "boulder-clay" are two common terms used for lodgement till. Ablation or "melt-out" till occurs as the ice sheet melts or stagnates away. Debris bands are laid down or stacked as the ice between the bands melts. Ablation till tends to be less dense, less compacted, and slightly coarser as meltwater commonly washes away some of the fine silt and clay. There is evidence that some of the tills were deposited in a water environment in southeastern Fulton 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. Such tills may more closely resemble lacustrine deposits. Reimann (1979) and Forsyth (1960) discuss the presence of an “upper” clayey, less compact (dense) till and a “lower” loamier, stony, dense till. This relationship of tills is common in many other parts of Ohio (White, 1982 and Steiger and Holowaychuk, 1971).

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), Reimann (1983), and Plymale (1999) discuss 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 Fulton County are listed in Table 9. 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)

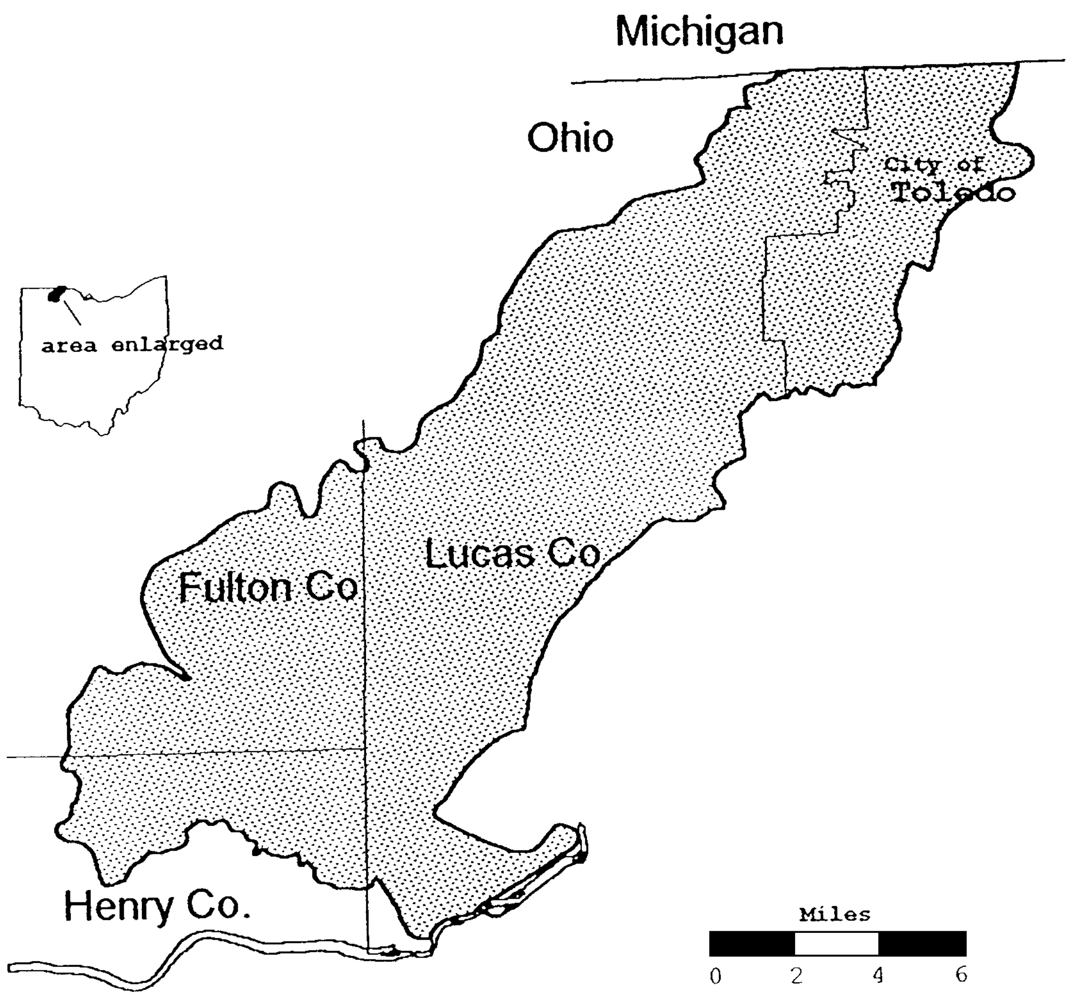
Lake Stage	Age (Years B.P)	Elevation (ft.)	Outlet	Found in Fulton County
Erie (modern)	4,000	573	Niagara	no
Algonquin	> 12,000	605	Grand River, Mi or Mohawk River, N.Y.	no
Lundy	>12,200	?	Grand River, Mi or Mohawk River, N.Y.	no
(Elkton)		615	Grand River, Mi or Mohawk River, N.Y.	no
(Dana)		620	Grand 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	yes
Lower Maumee		760	Grand River, Mi	yes
Upper Maumee		800	Wabash River, In	yes

Southeastern and central Fulton Henry County contain 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 larger body extends from northeastern Henry County 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 Reimann, 1979). 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 Tiffin River and other tributary streams (Reimann, 1979 and Plymale, 2002). These sand and gravel lenses are interbedded with finer-grained alluvial (floodplain) deposits. Some of these deposits receive recharge directly from the overlying streams. Sand and gravel deposits are interbedded in the thick sequence of glacial till associated with the buried valley that extends from Fayette to Lyons.

Sand and gravel outwash deposits underlie the lacustrine deposits in west-central Fulton County Reimann, 1979 and Plymale, 1999). These outwash deposits roughly lie between the Defiance Moraine and the Fort Wayne Moraine. A belt of flowing-wells is associated with these deep outwash deposits (Reimann, 1979 and Walker, 1991). These sand and gravel deposits tend to thin and fine to the north (Plymale, 1979). Deep, localized sand and gravel outwash deposits also underlie the Defiance Moraine and Fort Wayne Moraine.

Figure 4. Location of the Oak Openings sand body in northwest Ohio (Miller, 1997)



Bedrock Geology

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

The rock units throughout Fulton County are relatively flat-lying, dipping northwest roughly 20 feet per mile toward the Michigan Basin (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 hydrogoeolgy of the rock units in the region. None of the bedrock in Fulton County is exposed at the surface. All of the information on bedrock units is inferred from water well log data or from geologic maps and reports

Devonian-age limestones and dolomites comprise the uppermost bedrock units in the southeastern corner of Fulton County. 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. These rocks were deposited in warm shallow seas.

Devonian age Ohio Shale (Palombo, 1983 and Miller, 1997), Antrim Shale (ODNR, Division of Water, Bedrock State Aquifer Map, 2000) underlies much of southern and eastern Fulton County. These thick, dark brown to black fissile shales were deposited in deep oceans that had limited circulation of fresher waters and sediments. These shales are rich in organic matter, pyrite, and locally, natural gas. The northern and western portions of the county are underlain by Shales of the Mississippian Coldwater Shale (ODNR, Division of Water, Bedrock State Aquifer Map, 2000), Cuyahoga Formation (Reimann, 1979 and Plymale, 1999) and the Mississippian Sunbury-Berea-Bedford undivided (Reimann, 1979 and ODNR, Division of Water, Bedrock State Aquifer Map) underlie the northern and western portions of the county.

Table 10. BEDROCK STRATIGRAPHY OF FULTON COUNTY, OHIO

System	Group - Formation	Description
Mississippian	Sunbury – Berea – Bedford undivided	Gray to black, carbonaceous shales. Thinly laminated, fissile, thin bedded. Poor source of ground water.
Devonian	Traverse Group	Varies from fossiliferous limestone to cherty or sandy dolomite. May include minor shales. Yields range from 0 – 25 gpm.
	Dundee Limestone	
	Detroit River Group	

Ground Water Resources

Ground water in Fulton County is obtained from both unconsolidated (glacial-alluvial) and consolidated (bedrock) aquifers. Glacial aquifers are primarily associated with sequences of lenses of sand and gravel interbedded with till and lacustrine material. These sand and gravel deposits tend to be thicker and more continuous in the buried valley between Lyons and Fayette and in the area of flowing wells between the Defiance Moraine and Fort Wayne Moraine. Shallow sand and gravel aquifers are also associated with the surficial beach ridge deposits. The carbonate aquifer is an important regional aquifer for most of northwestern Ohio.

Carbonate aquifers are limited to the southeastern corner of Fulton County. These aquifers are used when wells cannot be completed in the overlying sand and gravel deposits. Yields from the Detroit River Group, Dundee Limestone, and the Traverse Group are moderate, ranging from 5 to 25 gpm up to 25 to 100 gpm (ODNR, Div. of Water, Open File, Bedrock State Aquifer Map, 2000, ODNR, Div. of Water, 1970, Reimann, 1979, Walker, 1991, and Plymale, 1999). Yields exceeding 100 gpm (ODNR, Div. of Water, Open File, Bedrock State Aquifer Map, 2000, ODNR, Div. of Water, 1970, and Walker, 1991) are available from deep, larger diameter wells drilled into the underlying Salina Undifferentiated Group, Tymochtee-Greenfield Formations, and the Lockport Group. These Silurian-age limestones and dolomites contain abundant vuggy (porous) zones and solution features. Yields over 100 gpm are obtained from these units. The water quality in these formations deteriorates with depth in many of these areas as the water becomes more mineralized and the sulfur content increases (ODNR, Div. of Water, 1970).

Shale overlies the carbonate aquifer farther north along the eastern margin of Fulton County (Walker, 1991). Deeper wells penetrate the shale and obtain yields up to 100 gpm from the limestone. The quality of this water is typically quite poor; containing high sulfur and iron and being highly mineralized.

Yields from the various Devonian and Mississippian-age shales are commonly less than 5 gpm (Reimann, 1979, Walker, 1991, ODNR, Division of Water, State Bedrock Aquifer Map, 2000, and Plymale, 1999). Typically, the uppermost 10 to 15 feet of the shale is weathered and broken and provides the most water. Wells drilled deeper into the shale provide increased well storage, but typically little additional water. Historically, shallow dug wells have been common in the shale. The water quality becomes more objectionable with depth.

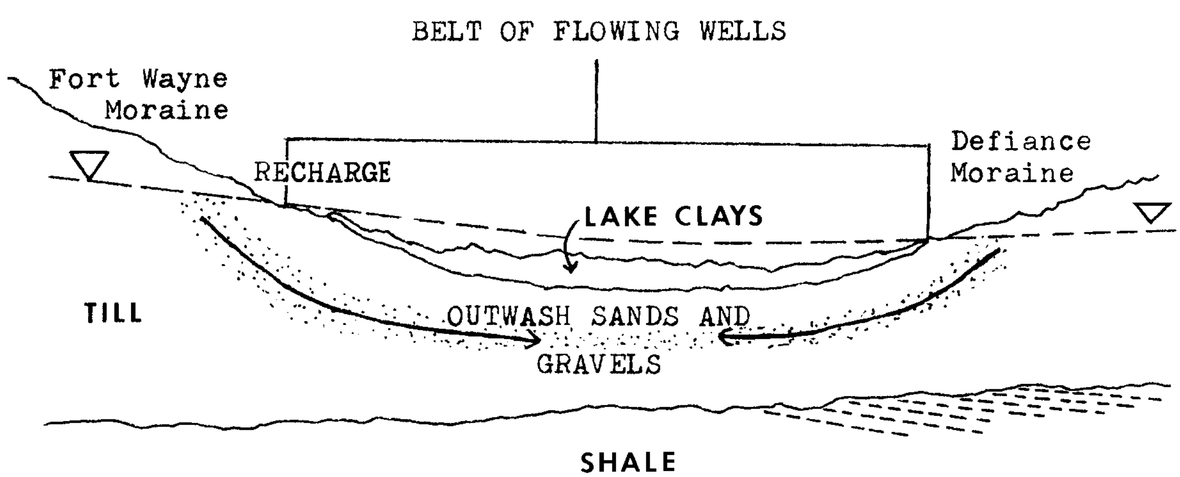
Yields from glacial aquifers vary considerably across Fulton County. Yields increase greatly in the western third of the county; west of a line roughly extending from Archbold to Lyons. East of this line, yields from sand and gravel lenses interbedded with the fine-grained till and lacustrine deposits averages 5 to 25 gpm (ODNR, Div. of Water, Glacial State Aquifer Map, 2000, Reimann, 1979, Walker, 1991, and Plymale, 1999). The sand and gravel may also directly overlie the bedrock (Reimann, 1979 and Plymale, 1999) and yield 5 to 25 gpm. The sand and gravel directly underlying the till boundary may undergo cementation due to the chemical precipitation of iron and calcite. Such localized zones are very hard and are referred to by well drillers as hardpan. (Note- Hardpan may also refer to dense till in some logs). Typically, the sand and gravel in eastern Fulton County is dirty, poorly-sorted, and consists primarily of ground-up shale fragments. Sand and gravel lenses are more commonly associated with the lower, loamier till (Reimann, 1979 and Forsyth, 1960). 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. Historically, shallow dug wells obtained water from the weathered glacial till.

In the western third of the county, yields increase significantly. Sand and gravel deposits tend to be thicker, more laterally continuous, coarser-grained and better sorted. Yields from properly developed, large diameter wells yield over 100 gpm. Higher yields in particular are associated with the terraces and outwash deposits adjacent to the Tiffin River, along the buried valley that extends from Lyons to Fayette, and from the deep outwash deposits between the Defiance Moraine and Fort Wayne Moraine. The 7Fb-Glacial Lake Deposits over Outwash setting was created to address the flowing wells and confined aquifer conditions associated with these deep outwash deposits. Fig. 5 is a diagram showing the hydrogeologic conditions in this zone of flowing wells and confining conditions.

The sand and gravel beach ridges are utilized as local aquifers in southeastern and central Fulton County. The Oak Openings in southeastern Fulton County represent some of the thickest, most widespread beach deposits in the state (Reimann, 1979, Hallfrisch, 1987, and Plymale, 1999, and ODNR, Div. of Water, Open File, Glacial State Aquifer Map, 2000). Beach ridges and overlying dunes are primarily composed of relatively fine-grained sand; however the basal section of some of these ridges contains coarse gravel and sand. The fine sands tend to store a large amount of water, but have moderately slow permeability. The water tends to perch or collect in the beach deposits that overlie the dense, low permeability lacustrine deposits or tills. Permeability and yields are moderate in the fine sand zones and average 5 to 25 gpm. Yields may increase in the coarser gravel-bearing zones.

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

Figure 5. Probable hydrogeologic conditions responsible for the confined belt of flowing wells in northwest Fulton County (after Reiman, 1979 and Plymale, 1999)



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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 Water, Water Resources Section (WRS). Depth to water data was taken directly from the thesis of Plymale (1999) for most areas. Approximately 4,400 water well log records are on file for Fulton County. Data from roughly 800 located water well log records were analyzed and plotted on U.S.G.S. 7-1/2 minute topographic maps during the course of the project. Static water levels and information as to the depths water was encountered at were taken from these records. The Ground Water Resources of Fulton County (Walker, 1991) and the thesis of Reimann (1979) provided generalized depth to water information throughout the county. Depth to water trends mapped in adjoining Lucas County (Hallfrisch, 2002), Williams County (Angle and Ziss, 2002), and Henry County (Miller and Angle, 2002 and Miller, 1997) were used as a guideline. Topographic and geomorphic trends were utilized in areas where other sources of data were lacking.

Depths to water are highly variable in Fulton County. Depths to water of 0 to 5 (10) were used for some limited floodplain areas adjacent to the Tiffin River and for portions of the Oak Openings sands in north of Wauseon. Depths of 5 to 15 feet (9) were selected for the Oak Opening beach ridges in the southeastern corner of Fulton County and north of Wauseon. Depths of 15 to 30 feet (7) were mapped for many of the sand and gravel aquifers in the northwestern and north-central portions of the county and for fringes of the Oak Openings sands in the southeast. Depths of 30 to 50 feet (5) were used extensively for shale and sand and gravel aquifers in the central and northwestern portions of the county. Depths to water of 50 to 75 feet (3) were utilized for higher elevation areas in the southwestern and south-central portions of the county. These areas commonly have shale aquifers. Depths of 50 to 75 feet (3) were also selected for portions of the buried valley. Depths of 75 to 100 (2) feet were used for areas containing very thick till overlying the sand and gravel or shale aquifers. Depths greater than 100 feet were typically used for confined aquifers. For confined aquifers, the depth to water is the top of the bedrock or sand and gravel aquifers. These confined aquifers include the area of flowing wells between the Defiance Moraine and Fort Wayne Moraine and the deep sand and gravel aquifers in the northeastern corner of the county (Fig 5).

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 Plymale (1999). Recharge values were extrapolated from adjacent Williams County (Coen, 1989). The Soil Survey of Fulton County (Stone and Michael, 1984) proved useful in determining the recharge rates. The thesis of Hallfrisch (1987) was helpful in evaluating the Oak Openings sands. Recharge ratings from Lucas County (Hallfrisch, 2002), Williams County (Angle and Ziss, 2002), and Henry County (Miller and Angle, 2002) 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 southeastern Fulton County. Recharge values of 7 to 10 inches per year (8) were assigned to areas of the Oak Openings containing somewhat thinner or finer sands. Values of 4 to 7 inches per year (6) were used for areas with moderate recharge. These areas include most of northwestern and central Fulton County. Values of 2 to 4 inches per year (3) were utilized for many areas containing thick clayey tills, clay-rich soils, and less permeable aquifers. These areas include most of southwestern Fulton County and much of north-central Fulton County. Recharge values of 0 to 2 inches per year (1) were selected for the areas with confining aquifer conditions. This included the 7Fb-Glacial Lake Deposits over Outwash setting that consists of an area of flowing wells between the Fort Wayne Moraine and Defiance Moraine. Confining conditions also exist in the area of thick drift in the northeastern corner of then county.

Aquifer Media

Information on evaluating aquifer media was obtained from the maps and reports of the Schmidt and Walker (1954), ODNR, Div. of Water (1970), Reimann (1979), Walker (1991), Hallfrisch (1987). 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 Plymale (1999). Aquifer ratings in neighboring Lucas County (Hallfrisch, 2002), Williams County (Angle and Ziss, 2002), and Henry County (Miller and Angle , 2002) were used as a guideline. The ODNR, Division of Water, Glacial State Aquifer Map and Bedrock State Aquifer Map were an important source of aquifer data. Water well log records on file at the ODNR, Division of Water, were the primary source of aquifer information.

Aquifers in Fulton County are quite variable. Shallow aquifers associated with the Oak Openings sands were evaluated as being unconfined. Many of the bedrock and thin sand and gravel aquifers were evaluated as being semi-confined or leaky;

however for the purposes of DRASTIC, they have been evaluated as being unconfined (Plymale, 1999 and Aller et al, 1987). Deep sand and gravel and shale aquifers in the northeastern corner of the county were evaluated as being confined aquifers. The deep sand and gravel outwash aquifers in the 7Fb-Glacial Lake Deposits over Outwash setting were also evaluated as being confined. Massive limestone was not evaluated as the aquifer in the southeastern corner of the county as it was believed the overlying sand and gravel aquifers associated with the Oak Openings represented a more vulnerable aquifer (Plymale, 1999) An aquifer rating of (2) was selected for the shale aquifers due to overall low permeability and yields of these rocks.

An aquifer rating of (9) was chosen for the thick, continuous sand and gravel outwash deposits north of Wauseon (Plymale, 1999). An aquifer rating of (8) was selected for the sand and gravel outwash deposits associated with the 7D-Buried Valley setting southwest of Lyons, the outwash adjacent to the Tiffin River, and outwash deposits northwest of Delta. Sand and gravel deposits underlying the 7Fb-Glacial Lake Deposits over Outwash setting were given an aquifer rating of (8) to the southwest and a (7) to the north as these units tended to fine (Plymale, 1999). Plymale assigned an aquifer rating of (7) to sand and gravel aquifers located in the 7C-Moraine setting. A rating of (7) was given to the clean sands of the Oak Openings beach ridges in southeastern and central Fulton County. Aquifer ratings of (6) or (7) were applied to sand and gravel lenses interbedded with fine-grained lacustrine deposits or till in northeastern Fulton County. The ratings depended upon how thick, continuous, coarse, and well sorted the various lenses were (Plymale, 1999).

Soils

Soils were mapped using the data obtained from the Soil Survey of Fulton County (Stone and Michael, 1984). 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 Fulton 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 Fulton County.

Soils were considered to be gravel (10) for a limited area of outwash and kettles along the Henry 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 two areas of the Oak Openings. A limited number of peat soils (8) were selected for isolated, wetland depressions. Shrink-swell (aggregated) clay (7) was selected for most of the high-clay lacustrine soils and the high clay wave-planed glacial till. Some of the soils derived from clayey tills covering end moraines and ground moraines were also evaluated as shrink-swell clay (7) soils. These soils expand upon wetting and are relatively impermeable during normal to wet conditions. They behave similar to clay loams at these times. During dry summer months, these soils desiccate and shrink, creating large cracks or fractures that serve as effective avenues for contaminants to migrate downward into the water table. These soils are the most widespread of all soils in Fulton County. Sandy loams (6) were selected for soils overlying beach ridges, especially for ridges separate from the Oak Openings sand bodies. Sandy loams (6) were also chosen for some stream terraces along the Tiffin River and various outwash deposits. Loam soils (5) were designated for medium-textured soils overlying floodplain terraces and outwash deposits. Silt loam (4) soils were evaluated for silty alluvial deposits particularly in the headwaters of tributaries. Silt loam (4) was also used for silty deltaic and lacustrine deposits. Clay loam (3) soils were evaluated for areas with moderately clay-rich lacustrine or alluvial sediments.

Table 11. DRASTIC RATINGS FOR FULTON COUNTY SOILS

Soil Name	Parent Material or Setting	DRASTIC Rating	Soil Media
Adrian	lacustrine – depression	2	muck
Bixler	beach, delta	6	sandy loam
Blount	till – moraine	3	clay loam
Blount - Rimer	till – moraine	3	clay loam
Boyer	beach, delta	9	sand
Brady	beach, delta	6	sandy loam
Cohoctah	alluvium	6	sandy loam
Colwood	delta	4	silt loam
Del Rey	delta	4	silt loam
Digby	beach	6	sandy loam
Dixboro	beach, delta	6	sandy loam
Eel	alluvium	3	clay loam
Fulton	lacustrine	7	shrink/swell clay
Galen	beach, dune	9	sand
Gilford	beach, delta	6	sandy loam
Glynwood	till – moraine	3	clay loam
Granby	beach,dune	6	sandy loam
Haskins	beach over till	3	clay loam
Hoytville	wave-modified till	7	shrink swell clay
Kibbie	delta	4	silt loam
Lamson	beach, delta	6	sandy loam
Latty	lacustrine	7	shrink/swell clay
Lenawee	lacustrine, delta	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
Ottokee	beach, dune	9	sand
Perrin	beach, dune	6	sandy loam
Pewamo	till	3	clay loam
Rawson	beach over lacustrine	7	shrink/swell clay
Rimer	beach over till	7	shrink/swell clay
Seward	beach over till	7	shrink/swell clay
Shinrock	lacustrine	7	shrink/swell clay
Shrinrock – Tuscola	delta over lacustrine	7	shrink/swell clay
Shoals	alluvium	4	silt loam
Sloan	alluvium	3	clay loam
Spinks	beach, dune	9	sand

TABLE 11 (continued). DRASTIC RATING FOR FULTON COUNTY SOILS

Soil Name	Parent Material or Setting	DRASTIC Rating	Soil Media
Tedrow	beach, dune	9	sand
Tuscola	delta	4	silt loam
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 Fulton County (Stone and Michael, 1984). Slopes of 0 to 2 percent (10) and 2 to 6 percent (9) were selected for almost all of the settings for Fulton 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 limited areas of the 7C-Moraine setting that formed a steeper ridge.

Impact of the Vadose Zone Media

Information on vadose zone media was obtained from the maps and reports of the Schmidt and Walker (1954), ODNR, Div. of Water (1970), Reimann (1979), Walker (1991), Hallfrisch (1987). 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 Plymale (1999). Vadose zone ratings in neighboring Lucas County (Hallfrisch, 2002), Williams County (Angle and Ziss, 2002), and Henry County (Miller and Angle , 2002) were used as a guideline. The ODNR, Division of Water, Glacial State Aquifer Map and Bedrock State Aquifer Map were an important source of vadose zone media data. Water well log records on file at the ODNR, Division of Water, were the primary source of vadose information.

The vadose zone media is a critical component of the overall DRASTIC rating in Fulton County (Plymale, 1999). The rating varies with the restrictive properties of the various glacial materials. The higher the proportion of silt and clay and the greater the compaction (density) of the sediments, the lower the permeability and the lower the vadose zone media are rated.

Sand and Gravel with Silt and Clay with ratings of (9) or (8) were selected as the vadose zone material for the coarse outwash deposits north of Wauseon. Sand and

Gravel with Silt and Clay with a rating of (7) was assigned to beach ridge deposits associated with the Oak Openings in southeastern Fulton County. Sand and Gravel with Silt and Clay with a rating of (6) was used for areas with moderately extensive, moderately coarse, and moderately thick sand and gravel. Sand and Gravel with Silt and Clay with a rating of (5) was applied to the thin sand and gravel lenses of the 7Af-Sand and Gravel interbedded in Glacial Till as well as some finer-grained, thin beach deposits. Sand and gravel with Silt and Clay with a rating of (4) was utilized for glacial till in many portions of Fulton County. Silt and clay with a rating of (4) was used for both silty lacustrine deposits and for-finer-grained glacial till. Silt and clay with a rating of (3) was chosen for clayey lacustrine deposits and for areas of clayey till overlying shale.

The vadose zone media was evaluated as being a confining layer (1) for two main areas in Fulton County. The 7Fb-Glacial Lake Deposits over Outwash in western Fulton County was evaluated as having a confining layer of clayey lacustrine deposits. In the northeastern corner of the county, the thick, dense till was considered as being a confining layer to the underlying sand and gravel lenses or shale bedrock

Hydraulic Conductivity

Information on evaluating the hydraulic conductivity was obtained from the maps and reports of the Schmidt and Walker (1954), ODNR, Div. of Water, (1970), Reimann (1979), Hallfrisch (1987), and Walker (1991). Data was also obtained from the report of Coen (1989) from neighboring Williams County. 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 Plymale (1999). Hydraulic conductivity values obtained from adjacent Henry County (Miller, 1997 and Miller and Angle, 2002), Lucas County (Hallfrisch, 2002), and Williams County (Angle and Ziss, 2002) proved to be useful guidelines. The ODNR, Division of Water, Glacial State Aquifer Map and Bedrock State Aquifer Map were an important source of aquifer data. Water well log records on file at the ODNR, Division of Water, were the primary source of aquifer information. Textbook tables (Freeze and Cherry, 1979, Fetter, 1980, and Driscoll, 1986) were useful in obtaining estimated values for hydraulic conductivity in a variety of sediments.

Values for hydraulic conductivity correspond to aquifer ratings; i.e., the more highly rated aquifers have higher values for hydraulic conductivity. All of the shale aquifers were assigned a hydraulic conductivity rating of 1-100 gallons per day per foot squared (gpd/ft2).

A hydraulic conductivity rating of 300-700 gpd/ft2 (4) was selected for the sand and gravel outwash deposits with aquifer media ratings of (9), (8), and commonly

(7). These included most of the aquifers in the 7Ba-Outwash, 7Fb-Glacial Lake Deposits over Outwash, and 7D, Buried Valley settings. A hydraulic conductivity rating of 100-300 gpd/ft2 (2) was chosen for all of the remaining glacial aquifers. The lower rating was applied due to the very fine-grained nature of most of the beach deposits and the less coarse, more poorly-sorted to dirty nature of the sand and gravel lenses of the remaining settings.

APPENDIX B

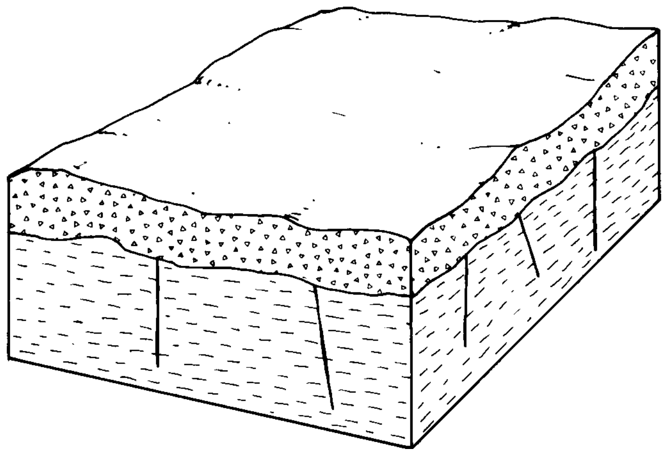
DESCRIPTION OF HYDROGEOLOGIC SETTINGS AND CHARTS

Ground water pollution potential mapping in Fulton County resulted in the identification of ten hydrogeologic settings within the Glaciated Central Region. The list of these settings, the range of pollution potential index calculations, and the number of index calculations for each setting are provided in Table 12. Computed pollution potential indexes for Fulton County range from 40 to 189.

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

Hydrogeologic Settings	Range of GWPP Indexes	Number of Index Calculations
7Ae - Glacial till over Shale	45 - 117	32
7Af - Sand and Gravel Interbedded in Glacial Till	93 - 147	32
7Ba - Outwash	137 - 189	20
7C - Moraine	90 - 182	17
7D - Buried Valley	41 - 158	30
7Ea - River alluvium with Overbank Deposits	159	1
7Ed - Alluvium over Glacial Till	40 - 153	15
7F - Glacial Lake Plains Deposits	41 - 151	97
7Fb - Glacial Lake Deposits over Outwash	63 - 79	19
7H - Beaches, Beach Ridge, and Sand Dunes	44-186	93
7I - Marshes and Swamps	151 - 173	2

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.



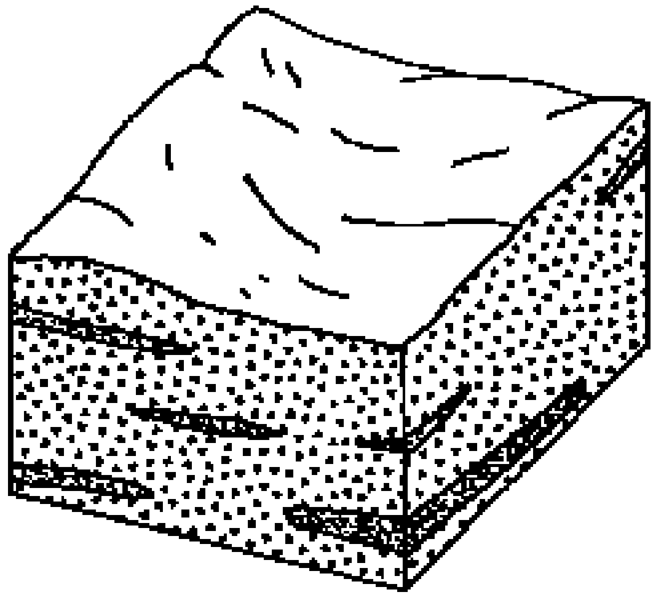
7Ae-Glacial Till over Shale

This hydrogeologic setting is common in to the northeastern and southwestern corners of Fulton County. The area is characterized by flat-lying topography and very low relief. The vadose zone is composed of loamy to clayey glacial till and clayey to silty lacustrine deposits. The till and shale overlying the aquifer is thick and dense enough to be considered a confining layer in portions of northeastern Fulton County. The till and clayey lacustrine sediments may be fractured or jointed, particularly in areas where it is predominantly thin and weathered. Depth to water is typically great, moderate depths are found closer to tributary streams. Soils are generally shrink-swell (aggregated) clays. Areas adjacent to beach ridges have sand or sandy loam soils. The aquifer is usually fractured, massive black Devonian-age shale. In some areas, wells are completed in thin lenses of dirty, shale–rich gravel that directly overly the shale. Yields from the shale are typically less than 5 gpm and range from 5 to 25 gpm for the shaley gravel lenses. Recharge is generally low due to the thick and clayey vadose zone and soils are and the great depth to water.

GWPP index values for the hydrogeologic setting of Glacial Till over Shale range from 45 to 117 with the total number of GWPP index calculations equaling 32.

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

Setting	Depth to water (ft.)	Recharge in./yr.	Aquifer Media	Soil Media	Topography % Slope	Vadose Zone Media	Hydro. Cond.	Rating
7Ae1	100+	0-2	Massive Shale	Sandy Loam	0-2	Confining Layer	1-100	45
7Ae2	100+	0-2	Massive Shale	S/S Clay	0-2	Confining Layer	1-100	47
7Ae3	100+	0-2	Massive Shale	Sand	0-2	Confining Layer	1-100	51
7Ae4	75-100	2-4	Massive Shale	Sandy Loam	2-6	Silt and Clay	1-100	67
7Ae5	100+	2-4	Massive Shale	Sandy Loam	2-6	Silt and Clay	1-100	62
7Ae6	100+	0-2	Sand and Gravel	Sandy Loam	0-2	Confining Layer	100-300	63
7Ae7	75-100	2-4	Massive Shale	Silty Loam	0-2	Silt and Clay	1-100	64
7Ae8	100+	2-4	Massive Shale	S/S Clay	2-6	Silt and Clay	1-100	64
7Ae9	100+	2-4	Massive Shale	S/S Clay	0-2	Silt and Clay	1-100	65
7Ae10	100+	0-2	Sand and Gravel	S/S Clay	0-2	Confining Layer	100-300	65
7Ae11	100+	0-2	Sand and Gravel	Sand	0-2	Confining Layer	100-300	69
7Ae12	75-100	0-2	Sand and Gravel	S/S Clay	0-2	Confining Layer	100-300	70
7Ae13	50-75	2-4	Massive Shale	Silty Loam	0-2	Silt and Clay	1-100	69
7Ae14	75-100	2-4	Massive Shale	Sand	2-6	Silt and Clay	1-100	73
7Ae15	50-75	2-4	Massive Shale	S/S Clay	0-2	Silt and Clay	1-100	75
7Ae16	30-50	2-4	Massive Shale	Sandy Loam	0-2	Silt and Clay	1-100	83
7Ae17	30-50	2-4	Massive Shale	S/S Clay	0-2	Silt and Clay	1-100	85
7Ae18	15-30	2-4	Massive Shale	Clay Loam	0-2	Silt and Clay	1-100	92
7Ae19	75-100	4-7	Massive Shale	Sandy Loam	2-6	Sand and Gravel	1-100	89
7Ae20	75-100	4-7	Massive Shale	S/S Clay	2-6	Sand and Gravel	1-100	91
7Ae21	75-100	4-7	Massive Shale	S/S Clay	0-2	Sand and Gravel	1-100	92
7Ae22	15-30	4-7	Massive Shale	S/S Clay	0-2	Sand and Gravel	1-100	117
7Ae23	15-30	2-4	Massive Shale	Silty Loam	0-2	Silt and Clay	1-100	94
7Ae24	50-75	4-7	Massive Shale	S/S Clay	2-6	Sand and Gravel	1-100	96
7Ae25	50-75	4-7	Massive Shale	S/S Clay	0-2	Sand and Gravel	1-100	97
7Ae26	15-30	2-4	Massive Shale	S/S Clay	0-2	Silt and Clay	1-100	95
7Ae27	15-30	2-4	Massive Shale	S/S Clay	0-2	Silt and Clay	1-100	100
7Ae28	30-50	4-7	Massive Shale	Sandy Loam	0-2	Sand and Gravel	1-100	105
7Ae29	30-50	4-7	Massive Shale	S/S Clay	0-2	Sand and Gravel	1-100	107
7Ae30	30-50	2-4	Sand and Gravel	Sandy Loam	2-6	Silt and Clay	300-700	106
7Ae31	15-30	2-4	Sand and Gravel	S/S Clay	0-2	Silt and Clay	100-300	115
7Ae32	75-100	2-4	Massive Shale	S/S Clay	0-2	Silt and Clay	1-100	70



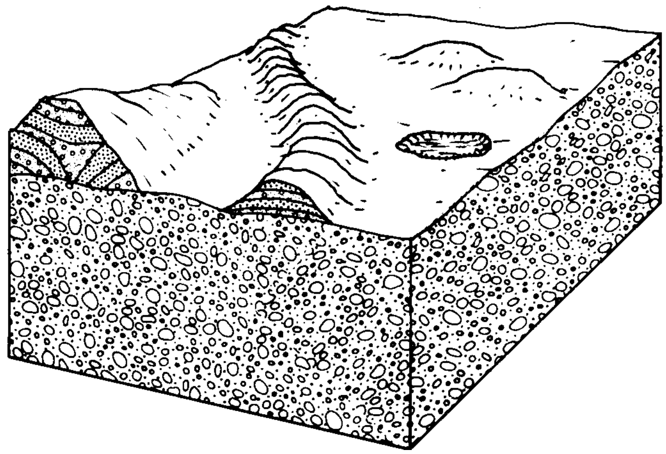
7Af-Sand and Gravel Interbedded in Glacial Till

This hydrogeologic setting is most common in the northwestern corner of Fulton County. The area is characterized by flat-lying topography and very low relief. The vadose zone is composed of silty to clayey glacial till. The till may be fractured or jointed, particularly in areas where it is predominantly thin and weathered. Depth to water is usually shallow, averaging less than 30 feet. Soils are generally shrink-swell (aggregated) clays or clay loams. The aquifer consists of thin lenses of sand and gravel interbedded in the glacial till. This setting is similar to the neighboring 7Ba-Outwash and 7D-Buried Valley settings except that the sand and gravel lenses are thinner and less continuous. Groundwater yields range from 5 to 25 gpm. Recharge is moderate due to the relatively shallow depth to water, flatter topography, and the relatively low permeability of the clayey soils and vadose.

GWPP index values for the hydrogeologic setting of Sand and Gravel Interbedded in Glacial Till range from 93 to 147 with the total number of GWPP index calculations equaling 32.

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

Setting	Depth to water (ft.)	Recharge in./yr.	Aquifer Media	Soil Media	Topography % Slope	Vadose Zone Media	Hydro. Cond.	Rating
7Af1	50-75	2-4	Sand and Gravel	Sand	2-6	Silt and Clay	100-300	93
7Af2	50-75	2-4	Sand and Gravel	S/S Clay	2-6	Sand and Gravel	100-300	94
7Af3	50-75	2-4	Sand and Gravel	S/S Clay	2-6	Silt and Clay	300-700	95
7Af4	50-75	2-4	Sand and Gravel	S/S Clay	0-2	Silt and Clay	100-300	95
7Af5	50-75	2-4	Sand and Gravel	S/S Clay	0-2	Silt and Clay	300-700	96
7Af6	30-50	2-4	Sand and Gravel	S/S Clay	0-2	Silt and Clay	300-700	109
7Af7	30-50	2-4	Sand and Gravel	S/S Clay	0-2	Sand and Gravel	100-300	108
7Af8	50-75	4-7	Sand and Gravel	S/S Clay	0-2	Sand and Gravel	100-300	117
7Af9	15-30	4-7	Sand and Gravel	Silty Loam	0-2	Silt and Clay	100-300	121
7Af10	15-30	2-4	Sand and Gravel	Sandy Loam	2-6	Silt and Clay	300-700	121
7Af11	30-50	4-7	Sand and Gravel	S/S Clay	0-2	Sand and Gravel	100-300	127
7Af12	15-30	4-7	Sand and Gravel	Silty Loam	0-2	Sand and Gravel	100-300	126
7Af13	30-50	4-7	Sand and Gravel	S/S Clay	2-6	Sand and Gravel	100-300	126
7Af14	15-30	4-7	Sand and Gravel	S/S Clay	0-2	Silt and Clay	100-300	127
7Af15	15-30	4-7	Sand and Gravel	Silty Loam	0-2	Sand and Gravel	100-300	131
7Af16	5-15	4-7	Sand and Gravel	S/S Clay	0-2	Sand and Gravel	100-300	147
7Af17	15-30	4-7	Sand and Gravel	S/S Clay	0-2	Sand and Gravel	100-300	137
7Af18	0-5	2-4	Sand and Gravel	Silty Loam	0-2	Silt and Clay	300-700	131
7Af19	15-30	4-7	Sand and Gravel	S/S Clay	0-2	Sand and Gravel	100-300	132
7Af20	15-30	4-7	Sand and Gravel	S/S Clay	0-2	Sand and Gravel	100-300	132
7Af21	15-30	4-7	Sand and Gravel	Sandy Loam	2-6	Sand and Gravel	100-300	134
7Af22	15-30	4-7	Sand and Gravel	S/S Clay	2-6	Sand and Gravel	100-300	136
7Af23	15-30	4-7	Sand and Gravel	S/S Clay	0-2	Sand and Gravel	100-300	137
7Af24	5-15	4-7	Sand and Gravel	Clay Loam	0-2	Sand and Gravel	100-300	139
7Af25	15-30	4-7	Sand and Gravel	S/S Clay	0-2	Sand and Gravel	100-300	137
7Af26	0-5	2-4	Sand and Gravel	S/S Clay	0-2	Silt and Clay	300-700	137
7Af27	15-30	4-7	Sand and Gravel	Silty Loam	0-2	Sand and Gravel	300-700	138
7Af28	0-5	4-7	Sand and Gravel	S/S Clay	0-2	Sand and Gravel	100-300	147
7Af29	15-30	4-7	Sand and Gravel	S/S Clay	2-6	Sand and Gravel	300-700	143
7Af30	15-30	4-7	Sand and Gravel	Sandy Loam	0-2	Sand and Gravel	100-300	135
7Af31	15-30	2-4	Sand and Gravel	Sandy Loam	0-2	Silt and Clay	300-700	119
7Af32	15-30	4-7	Sand and Gravel	Sandy Loam	0-2	Silt and Clay	300-700	137



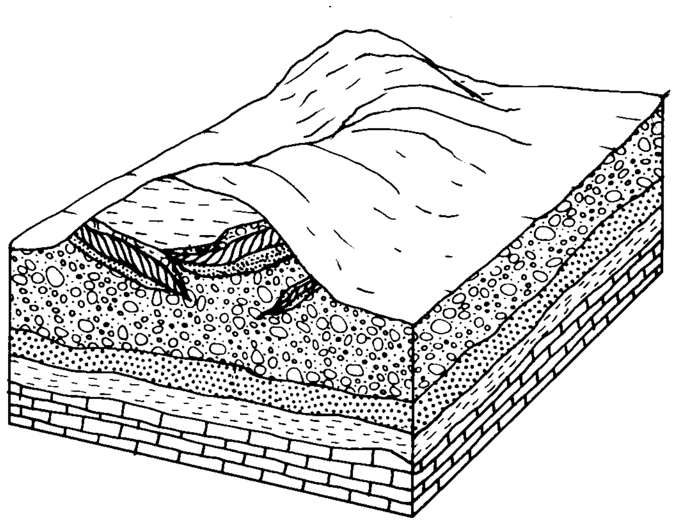
7Ba Outwash

This hydrogeologic setting consists of areas of outwash and kames in north-central Fulton County. This setting is characterized by flat-lying topography and low relief. The aquifer consists of relatively thick and continuous sand and gravel outwash deposits. These sand and gravel deposits tend to be shallower than in the neighboring 7D-Buried Valley and 7Fb-Glacial Lake Deposits over Outwash settings. Yields average 10 to 25 gpm with maximum local yields over 100 gpm. Test drilling may be necessary to locate higher-yielding areas. Vadose zone media consists of bedded sandy to gravelly outwash interbedded with varying thicknesses of glacial till. Depth to water is commonly shallow. Soils are usually shrink-swell (aggregated) clays. Soils are sandy loams or sand in areas adjacent to isolated beach ridges and dunes. Recharge is moderately high due to the relatively flat topography, relatively permeable soils and vadose media, and the shallow depth to water.

GWPP index values for the hydrogeologic setting of Outwash range from 137 to 189 with the total number of GWPP index calculations equaling 20.

Hydrogeologic Setting Values for: 7Ba-Outwash

Setting	Depth to water (ft.)	Recharge in./yr.	Aquifer Media	Soil Media	Topography % Slope	Vadose Zone Media	Hydro. Cond.	Rating
7Ba1	15-30	4-7	Sand and Gravel	S/S Clay	0-2	Sand and Gravel	300-700	149
7Ba2	15-30	4-7	Sand and Gravel	Sandy Loam	0-2	Sand and Gravel	100-300	138
7Ba3	15-30	4-7	Sand and Gravel	S/S Clay	0-2	Sand and Gravel	100-300	137
7Ba4	15-30	4-7	Sand and Gravel	S/S Clay	0-2	Sand and Gravel	100-300	140
7Ba5	15-30	4-7	Sand and Gravel	S/S Clay	2-6	Sand and Gravel	300-700	145
7Ba6	5-15	4-7	Sand and Gravel	S/S Clay	0-2	Silt and Clay	300-700	146
7Ba7	0-5	4-7	Sand and Gravel	Sandy Loam	2-6	Sand and Gravel	300-700	148
7Ba8	5-15	4-7	Sand and Gravel	S/S Clay	2-6	Sand and Gravel	300-700	148
7Ba9	15-30	4-7	Sand and Gravel	S/S Clay	2-6	Sand and Gravel	100-300	149
7Ba10	0-5	4-7	Sand and Gravel	S/S Clay	0-2	Sand and Gravel	300-700	151
7Ba11	15-30	4-7	Sand and Gravel	S/S Clay	0-2	Sand and Gravel	300-700	156
7Ba12	0-5	4-7	Sand and Gravel	Sandy Loam	0-2	Sand and Gravel	300-700	157
7Ba13	0-5	4-7	Sand and Gravel	Sandy Loam	2-6	Sand and Gravel	300-700	158
7Ba14	5-15	4-7	Sand and Gravel	S/S Clay	2-6	Sand and Gravel	300-700	158
7Ba15	0-5	4-7	Sand and Gravel	S/S Clay	0-2	Sand and Gravel	300-700	159
7Ba16	0-5	4-7	Sand and Gravel	S/S Clay	2-6	Sand and Gravel	300-700	160
7Ba17	0-5	4-7	Sand and Gravel	S/S Clay	0-2	Sand and Gravel	300-700	164
7Ba18	0-5	7-10	Sand and Gravel	S/S Clay	2-6	Sand and Gravel	300-700	184
7Ba19	0-5	7-10	Sand and Gravel	Sand	2-6	Sand and Gravel	300-700	188
7Ba20	0-5	7-10	Sand and Gravel	Sand	0-2	Sand and Gravel	300-700	189



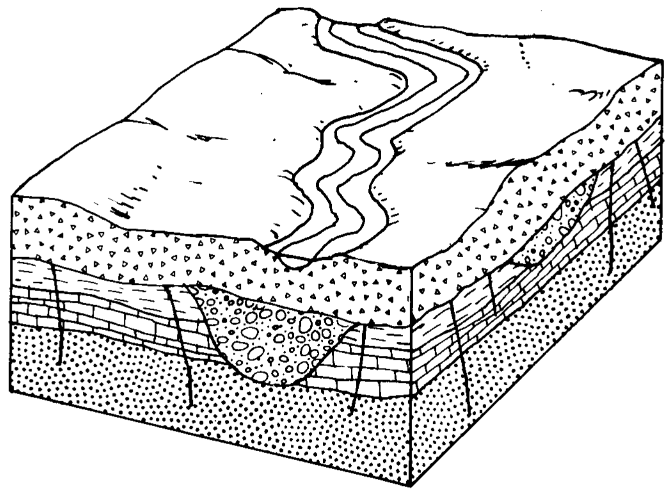
7C Moraine

This hydrogeologic setting consists of segments of the Defiance Moraine and Fort Wayne Moraine in northern Fulton County. This setting is characterized by hummocky to rolling topography and low relief. The aquifer consists of relatively thick and continuous sand and gravel outwash deposits underlying the moraine. These sand and gravel deposits are variable as to depth and thickness and are found at variable depths. Yields average 10 to 25 gpm with maximum local yields over 100 gpm. Test drilling may be necessary to locate higher-yielding areas. Vadose zone media consists of bedded sandy to gravelly outwash interbedded with varying thicknesses of glacial till. Depth to water is highly variable and is a function of how deep the sand and gravel lenses are. Soils are usually shrink-swell (aggregated) clays or sandy loams. Recharge is moderately to high depending upon the depth to water and how sandy the vadose zone and aquifer materials are in a given area.

GWPP index values for the hydrogeologic setting of Moraine range from 90 to 182 with the total number of GWPP index calculations equaling 17.

Hydrogeologic Setting Values for: 7C-Moraine

Setting	Depth to water (ft.)	Recharge in./yr.	Aquifer Media	Soil Media	Topography % Slope	Vadose Zone Media	Hydro. Cond.	Rating
7C1	50-75	2-4	Sand and Gravel	Sandy Loam	2-6	Silt and Clay	100-300	90
7C2	50-75	2-4	Sand and Gravel	Sand	2-6	Silt and Clay	100-300	96
7C3	15-30	2-4	Sand and Gravel	Sandy Loam	2-6	Silt and Clay	100-300	110
7C4	15-30	2-4	Sand and Gravel	S/S Clay	2-6	Silt and Clay	100-300	112
7C5	15-30	2-4	Sand and Gravel	Sandy Loam	2-6	Silt and Clay	100-300	115
7C6	15-30	2-4	Sand and Gravel	Sand	2-6	Silt and Clay	100-300	116
7C7	15-30	2-4	Sand and Gravel	S/S Clay	2-6	Silt and Clay	100-300	117
7C8	30-50	4-7	Sand and Gravel	Sandy Loam	6-12	Sand and Gravel	300-700	132
7C9	30-50	4-7	Sand and Gravel	Sandy Loam	2-6	Sand and Gravel	300-700	136
7C10	30-50	4-7	Sand and Gravel	S/S Clay	2-6	Sand and Gravel	300-700	138
7C11	30-50	4-7	Sand and Gravel	Sandy Loam	0-2	Sand and Gravel	300-700	142
7C12	15-30	4-7	Sand and Gravel	Sandy Loam	2-6	Sand and Gravel	300-700	143
7C13	15-30	4-7	Sand and Gravel	S/S Clay	0-2	Sand and Gravel	100-300	137
7C14	15-30	4-7	Sand and Gravel	Sand	2-6	Sand and Gravel	300-700	149
7C15	5-15	4-7	Sand and Gravel	Sand	2-6	Sand and Gravel	300-700	159
7C16	0-5	7-10	Sand and Gravel	S/S Clay	0-2	Sand and Gravel	300-700	179
7C17	0-5	7-10	Sand and Gravel	Sand	2-6	Sand and Gravel	300-700	182



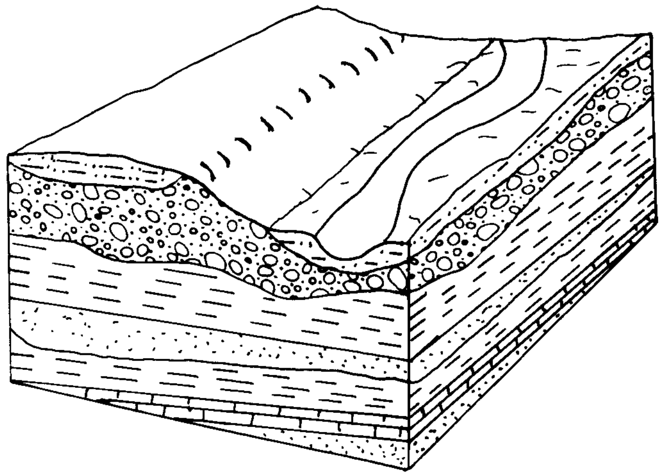
7D Buried Valleys

This hydrogeologic setting is found in northern Fulton County. The buried valley trends east-west roughly from Lyons to Fayette. The setting is characterized by flat-lying topography and low relief. The buried valley is not associated with a modern, overlying stream. Depths to water are variable; they tend to be shallower to the west and deeper to the east. The aquifers are commonly deep and are composed of sand and gravel outwash that vary in thickness. Yields average 5 to 25 gpm with larger diameter wells yielding over 100 gpm from higher-producing zones. Vadose zone media consists of bedded sandy to gravelly outwash interbedded with glacial till with varying thickness. Soils are primarily shrink-swell clays and clay loams. In the eastern end of the buried valley, the thickness of the till is sufficient for the till to be evaluated as a confining layer. Recharge is typically moderate to low due to the low permeability of the soils and vadose and the variable depth to water.

GWPP index values for the hydrogeologic setting of Buried Valley range from 41 to 158 with the total number of GWPP index calculations equaling 30.

Hydrogeologic Setting Values for: 7D - Buried Valleys

Setting	Depth to water (ft.)	Recharge in./yr.	Aquifer Media	Soil Media	Topography % Slope	Vadose Zone Media	Hydro. Cond.	Rating
7D1	100+	0-2	Sand and Gravel	S/S Clay	0-2	Confining Layer	100-300	65
7D2	100+	0-2	Sand and Gravel	S/S Clay	2-6	Confining Layer	100-300	64
7D3	100+	0-2	Sand and Gravel	Sandy Loam	2-6	Confining Layer	300-700	68
7D4	100+	0-2	Sand and Gravel	Sandy Loam	0-2	Confining Layer	300-700	69
7D5	75-100	0-2	Sand and Gravel	Sandy Loam	0-2	Confining Layer	300-700	74
7D6	75-100	0-2	Sand and Gravel	S/S Clay	0-2	Confining Layer	300-700	79
7D7	100+	0-2	Sand and Gravel	Sand	0-2	Confining Layer	300-700	75
7D8	75-100	0-2	Sand and Gravel	Sandy Loam	0-2	Confining Layer	300-700	77
7D9	30-50	2-4	Sand and Gravel	Loam	0-2	Silt and Clay	100-300	99
7D10	30-50	2-4	Sand and Gravel	S/S Clay	2-6	Silt and Clay	100-300	102
7D11	15-30	2-4	Sand and Gravel	Sandy Loam	0-2	Silt and Clay	100-300	111
7D12	15-30	2-4	Sand and Gravel	S/S Clay	2-6	Silt and Clay	100-300	112
7D13	15-30	2-4	Sand and Gravel	S/S Clay	0-2	Silt and Clay	100-300	113
7D14	50-75	4-7	Sand and Gravel	Sandy Loam	2-6	Sand and Gravel	100-300	117
7D15	50-75	4-7	Sand and Gravel	S/S Clay	2-6	Sand and Gravel	100-300	119
7D16	50-75	4-7	Sand and Gravel	Sand	2-6	Sand and Gravel	100-300	123
7D17	30-50	4-7	Sand and Gravel	Sandy Loam	2-6	Sand and Gravel	100-300	127
7D18	30-50	4-7	Sand and Gravel	S/S Clay	2-6	Sand and Gravel	100-300	129
7D19	5-15	4-7	Sand and Gravel	S/S Clay	2-6	Sand and Gravel	300-700	158
7D20	15-30	4-7	Sand and Gravel	Sandy Loam	2-6	Sand and Gravel	100-300	137
7D21	15-30	4-7	Sand and Gravel	Sandy Loam	0-2	Silt and Clay	300-700	137
7D22	30-50	4-7	Sand and Gravel	S/S Clay	2-6	Sand and Gravel	300-700	138
7D23	15-30	4-7	Sand and Gravel	S/S Clay	2-6	Sand and Gravel	100-300	139
7D24	15-30	4-7	Sand and Gravel	S/S Clay	2-6	Sand and Gravel	300-700	143
7D25	15-30	4-7	Sand and Gravel	Sandy Loam	2-6	Sand and Gravel	300-700	146
7D26	15-30	4-7	Sand and Gravel	Sandy Loam	0-2	Sand and Gravel	300-700	147
7D27	15-30	4-7	Sand and Gravel	S/S Clay	2-6	Sand and Gravel	300-700	148
7D28	15-30	4-7	Sand and Gravel	S/S Clay	0-2	Sand and Gravel	300-700	149
7D29	5-15	4-7	Sand and Gravel	Sandy Loam	0-2	Sand and Gravel	300-700	157
7D30	100+	0-2	Massive Shale	Silty Loam	0-2	Confining Layer	1-100	41



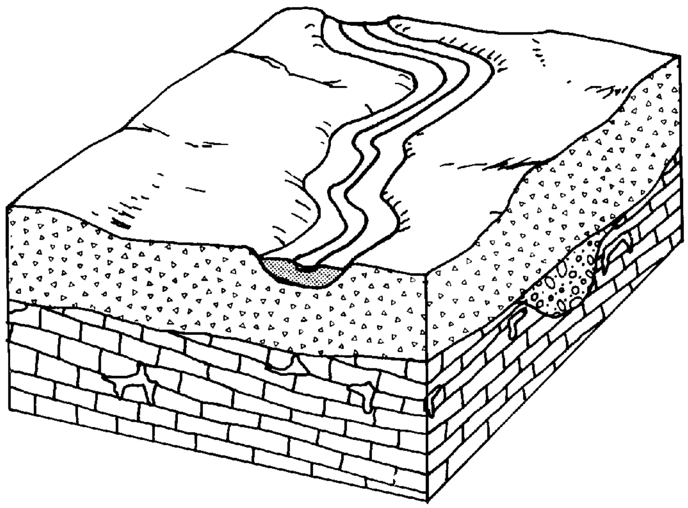
7Ea-River Alluvium with Overbank Deposits

This hydrogeologic setting is associated with a few minor tributaries that have their headwaters in southeastern Fulton County. Relatively narrow, flat-lying floodplains and low terraces characterize this setting. The vadose zone is comprised of clayey to silty floodplain deposits. Wells are developed in sand and gravel lenses underlying the floodplains. These lenses are interbedded with finer-grained alluvium, till, or lacustrine deposits. Yields range from 5 to 50 gpm. Soils are generally clay loams. Depth to water is typically shallow averaging less than 35 feet. Recharge is typically moderate to high due to shallow depth to water, flat topography, presence of overlying streams and low to moderate permeability soils and vadose zone materials.

The GWPP index value for the hydrogeologic setting of River Alluvium with Overbank Deposits is 159 with the total number of GWPP index calculations equaling 1.

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

Setting	Depth to water (ft.)	Recharge in./yr.	Aquifer Media	Soil Media	Topography % Slope	Vadose Zone Media	Hydro. Cond.	Rating
7Ea1	5-15	10+	Sand and Gravel	Clay Loam	0-2	Sand and Gravel	100-300	159



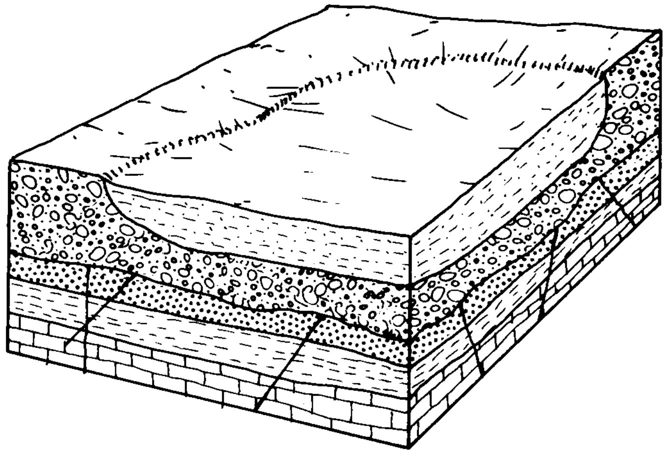
7Ed Alluvium Over Glacial Till

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 scattered throughout Fulton County. The setting typically represents the headwaters of small tributaries. 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 shale. 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 5 to 25 gpm from the sand and gravel and less than 5 gpm for the underlying shale. Depth to water is highly variable depending upon how deep the underlying sand and gravel lenses are. There may be a sufficient thickness of the overlying till to be evaluated as a confining layer. Recharge is variable depending upon the depth to the aquifer, the low permeability of the vadose zone, and whether the stream is in hydraulic connection with the underlying aquifer.

GWPP index values for the hydrogeologic setting of Alluvium over Glacial Till range from 40 to 153 with the total number of GWPP index calculations equaling 15.

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

Setting	Depth to water (ft.)	Recharge in./yr.	Aquifer Media	Soil Media	Topography % Slope	Vadose Zone Media	Hydro. Cond.	Rating
7Ed2	100+	0-2	Sand and Gravel	Silty Loam	0-2	Confining Layer	100-300	59
7Ed3	100+	0-2	Sand and Gravel	Silty Loam	0-2	Confining Layer	100-300	56
7Ed4	100+	0-2	Sand and Gravel	Silty Loam	0-2	Confining Layer	300-700	65
7Ed5	75-100	0-2	Sand and Gravel	Silty Loam	0-2	Confining Layer	100-300	64
7Ed6	100+	0-2	Sand and Gravel	Silty Loam	0-2	Confining Layer	300-700	68
7Ed7	75-100	0-2	Sand and Gravel	Silty Loam	0-2	Confining Layer	300-700	70
7Ed8	30-50	2-4	Massive Shale	Silty Loam	0-2	Sand and Gravel	1-100	84
7Ed9	15-30	2-4	Massive Shale	Silty Loam	0-2	Sand and Gravel	1-100	94
7Ed10	15-30	4-7	Sand and Gravel	Loam	0-2	Silt and Clay	100-300	123
7Ed11	15-30	4-7	Sand and Gravel	Silty Loam	2-6	Sand and Gravel	300-700	129
7Ed12	0-5	4-7	Sand and Gravel	Silty Loam	0-2	Silt and Clay	300-700	143
7Ed13	0-5	4-7	Sand and Gravel	S/S Clay	0-2	Silt and Clay	300-700	149
7Ed14	0-5	4-7	Sand and Gravel	Silty Loam	0-2	Sand and Gravel	300-700	153
7Ed15	15-30	4-7	Sand and Gravel	Silty Loam	0-2	Sand and Gravel	100-300	126



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 through most of southern and eastern Fulton County. The vadose zone media consists of silty to clayey lacustrine sediments or silty deltaic sediments that overlie glacial till. The till may be of sufficient thickness and density to be considered a confining layer. The aquifer consists of thin sand and gravel lenses interbedded in the underlying till or in the underlying shale bedrock. Yields are usually less than 5 gpm for the shale and range from 5 to 25 gpm up to 25 to 100 gpm for the sand and gravel lenses. Depths to water are highly variable and depend upon how deep the aquifer is. 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 dessication 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 41 to 151 with the total number of GWPP index calculations equaling 97.

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

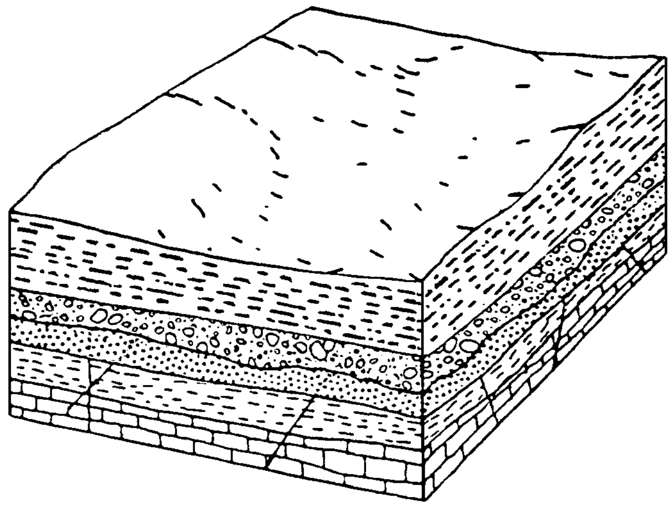
Setting	Depth to water (ft.)	Recharge in./yr.	Aquifer Media	Soil Media	Topography % Slope	Vadose Zone Media	Hydro. Cond.	Rating
7F1	100+	0-2	Massive Shale	Silty Loam	0-2	Confining Layer	1-100	41
7F2	100+	0-2	Massive Shale	Sandy Loam	0-2	Confining Layer	1-100	45
7F3	100+	0-2	Massive Shale	S/S Clay	2-6	Confining Layer	1-100	46
7F4	100+	0-2	Massive Shale	S/S Clay	0-2	Confining Layer	1-100	47
7F5	100+	0-2	Massive Shale	Sand	0-2	Confining Layer	1-100	51
7F6	100+	0-2	Sand and Gravel	Sandy Loam	2-6	Confining Layer	100-300	62
7F7	100+	0-2	Sand and Gravel	Sandy Loam	0-2	Confining Layer	100-300	63
7F8	75-100	2-4	Massive Shale	Silty Loam	0-2	Silt and Clay	1-100	64
7F9	100+	2-4	Massive Shale	S/S Clay	2-6	Silt and Clay	1-100	64
7F10	100+	0-2	Sand and Gravel	S/S Clay	2-6	Confining Layer	100-300	64
7F11	75-100	2-4	Massive Shale	Loam	2-6	Silt and Clay	1-100	65
7F12	100+	0-2	Sand and Gravel	S/S Clay	0-2	Confining Layer	100-300	65
7F13	100+	0-2	Sand and Gravel	Sand	0-2	Confining Layer	100-300	69
7F14	75-100	0-2	Sand and Gravel	S/S Clay	0-2	Confining Layer	100-300	70
7F15	75-100	2-4	Massive Shale	Sandy Loam	0-2	Silt and Clay	1-100	68
7F16	50-75	2-4	Massive Shale	Silty Loam	0-2	Silt and Clay	1-100	69
7F17	75-100	2-4	Massive Shale	S/S Clay	2-6	Silt and Clay	1-100	69
7F18	75-100	2-4	Massive Shale	S/S Clay	0-2	Silt and Clay	1-100	70
7F19	50-75	2-4	Massive Shale	Sandy Loam	2-6	Silt and Clay	1-100	72
7F20	50-75	2-4	Massive Shale	Sandy Loam	0-2	Silt and Clay	1-100	73
7F21	50-75	2-4	Massive Shale	Sandy Loam	2-6	Silt and Clay	1-100	72
7F22	50-75	2-4	Massive Shale	S/S Clay	2-6	Silt and Clay	1-100	74
7F23	75-100	2-4	Massive Shale	Sand	0-2	Silt and Clay	1-100	74
7F24	50-75	2-4	Massive Shale	S/S Clay	0-2	Silt and Clay	1-100	75
7F25	75-100	2-4	Massive Shale	S/S Clay	0-2	Silt and Clay	1-100	70
7F26	50-75	4-7	Massive Shale	Sandy Loam	2-6	Sand and Gravel	1-100	94
7F27	30-50	2-4	Massive Shale	Silty Loam	2-6	Silt and Clay	1-100	78
7F28	30-50	2-4	Massive Shale	Silty Loam	0-2	Silt and Clay	1-100	79
7F29	50-75	2-4	Massive Shale	Sand	2-6	Silt and Clay	1-100	78
7F30	30-50	2-4	Massive Shale	Sandy Loam	2-6	Silt and Clay	1-100	82
7F31	30-50	2-4	Massive Shale	Silty Loam	0-2	Silt and Clay	1-100	84
7F32	30-50	2-4	Massive Shale	S/S Clay	2-6	Silt and Clay	1-100	84
7F33	30-50	2-4	Massive Shale	S/S Clay	0-2	Silt and Clay	1-100	85
7F34	75-100	4-7	Massive Shale	Silty Loam	0-2	Sand and Gravel	1-100	86
7F35	50-75	2-4	Sand and Gravel	Silty Loam	0-2	Silt and Clay	100-300	87
7F36	30-50	2-4	Massive Shale	Sandy Loam	2-6	Sand and Gravel	1-100	87
7F37	30-50	2-4	Massive Shale	Sandy Loam	0-2	Silt and Clay	1-100	83
7F38	15-30	2-4	Massive Shale	Sandy Loam	0-2	Sand and Gravel	1-100	98
7F39	30-50	2-4	Massive Shale	Sandy Loam	0-2	Sand and Gravel	1-100	88
7F40	30-50	2-4	Massive Shale	Sand	2-6	Silt and Clay	1-100	88

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

Setting	Depth to water (ft.)	Recharge in./yr.	Aquifer Media	Soil Media	Topography % Slope	Vadose Zone Media	Hydro. Cond.	Rating
7F41	15-30	2-4	Massive Shale	Silty Loam	2-6	Silt and Clay	1-100	88
7F42	15-30	2-4	Massive Shale	Silty Loam	0-2	Silt and Clay	1-100	89
7F43	30-50	2-4	Massive Shale	S/S Clay	0-2	Sand and Gravel	1-100	90
7F44	75-100	4-7	Massive Shale	S/S Clay	0-2	Sand and Gravel	1-100	92
7F45	30-50	2-4	Massive Shale	Sandy Loam	0-2	Sand and Gravel	1-100	93
7F46	15-30	2-4	Massive Shale	Sandy Loam	0-2	Silt and Clay	1-100	93
7F47	50-75	2-4	Sand and Gravel	S/S Clay	0-2	Silt and Clay	100-300	93
7F48	30-50	2-4	Massive Shale	Sand	0-2	Silt and Clay	1-100	89
7F49	50-75	2-4	Sand and Gravel	Sandy Loam	0-2	Silt and Clay	100-300	94
7F50	50-75	4-7	Massive Shale	Sandy Loam	0-2	Sand and Gravel	1-100	95
7F51	30-50	2-4	Massive Shale	S/S Clay	0-2	Sand and Gravel	1-100	95
7F52	15-30	2-4	Massive Shale	S/S Clay	0-2	Silt and Clay	1-100	95
7F53	50-75	4-7	Massive Shale	S/S Clay	2-6	Sand and Gravel	1-100	96
7F54	50-75	2-4	Sand and Gravel	Sandy Loam	0-2	Sand and Gravel	100-300	99
7F55	50-75	2-4	Sand and Gravel	S/S Clay	0-2	Silt and Clay	100-300	96
7F56	50-75	4-7	Massive Shale	S/S Clay	0-2	Sand and Gravel	1-100	97
7F57	15-30	2-4	Massive Shale	Sandy Loam	0-2	Sand and Gravel	1-100	98
7F58	50-75	4-7	Massive Shale	Sandy Loam	2-6	Sand and Gravel	1-100	99
7F59	50-75	4-7	Massive Shale	Sandy Loam	0-2	Sand and Gravel	1-100	100
7F60	15-30	2-4	Massive Shale	S/S Clay	0-2	Sand and Gravel	1-100	100
7F61	30-50	4-7	Massive Shale	Silty Loam	0-2	Sand and Gravel	1-100	101
7F62	50-75	2-4	Sand and Gravel	S/S Clay	0-2	Silt and Clay	300-700	102
7F63	50-75	2-4	Sand and Gravel	Sand	2-6	Silt and Clay	100-300	99
7F64	30-50	2-4	Sand and Gravel	S/S Clay	0-2	Silt and Clay	100-300	103
7F65	30-50	4-7	Massive Shale	S/S Clay	0-2	Sand and Gravel	1-100	107
7F66	30-50	2-4	Sand and Gravel	S/S Clay	0-2	Silt and Clay	300-700	109
7F67	15-30	4-7	Massive Shale	Silty Loam	0-2	Sand and Gravel	1-100	111
7F68	30-50	2-4	Sand and Gravel	S/S Clay	2-6	Sand and Gravel	100-300	112
7F69	5-15	2-4	Sand and Gravel	S/S Clay	0-2	Silt and Clay	300-700	132
7F70	30-50	2-4	Sand and Gravel	S/S Clay	0-2	Sand and Gravel	100-300	113
7F71	15-30	2-4	Sand and Gravel	S/S Clay	0-2	Silt and Clay	100-300	113
7F72	50-75	4-7	Sand and Gravel	S/S Clay	0-2	Sand and Gravel	100-300	115
7F73	15-30	4-7	Massive Shale	Sandy Loam	0-2	Sand and Gravel	1-100	115
7F74	15-30	2-4	Sand and Gravel	Sandy Loam	0-2	Sand and Gravel	100-300	116
7F75	50-75	4-7	Sand and Gravel	S/S Clay	0-2	Sand and Gravel	100-300	118
7F76	15-30	4-7	Massive Shale	S/S Clay	0-2	Sand and Gravel	1-100	117
7F77	30-50	4-7	Massive Shale	S/S Clay	0-2	Sand and Gravel	1-100	117
7F78	30-50	4-7	Sand and Gravel	Sandy Loam	0-2	Sand and Gravel	100-300	123
7F79	30-50	4-7	Sand and Gravel	S/S Clay	0-2	Sand and Gravel	100-300	125
7F80	15-30	4-7	Massive Shale	Sandy Loam	0-2	Sand and Gravel	1-100	120

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

Setting	Depth to water (ft.)	Recharge in./yr.	Aquifer Media	Soil Media	Topography % Slope	Vadose Zone Media	Hydro. Cond.	Rating
7F81	15-30	2-4	Sand and Gravel	S/S Clay	0-2	Sand and Gravel	100-300	123
7F82	30-50	4-7	Sand and Gravel	S/S Clay	0-2	Sand and Gravel	100-300	125
7F83	30-50	4-7	Sand and Gravel	Sandy Loam	0-2	Sand and Gravel	100-300	123
7F84	30-50	4-7	Sand and Gravel	S/S Clay	0-2	Sand and Gravel	100-300	122
7F85	15-30	4-7	Massive Shale	Peat	0-2	Sand and Gravel	1-100	124
7F86	30-50	4-7	Sand and Gravel	S/S Clay	0-2	Sand and Gravel	100-300	125
7F87	30-50	4-7	Sand and Gravel	Sandy Loam	0-2	Sand and Gravel	100-300	123
7F88	30-50	4-7	Sand and Gravel	S/S Clay	0-2	Sand and Gravel	100-300	125
7F89	15-30	4-7	Massive Shale	Sand	0-2	Sand and Gravel	1-100	126
7F90	5-15	4-7	Massive Shale	Sandy Loam	0-2	Sand and Gravel	1-100	130
7F91	15-30	4-7	Massive Shale	Sandy Loam	0-2	Sand and Gravel	1-100	125
7F92	5-15	2-4	Sand and Gravel	Sand	2-6	Silt and Clay	300-700	135
7F93	5-15	2-4	Sand and Gravel	Sand	0-2	Silt and Clay	300-700	136
7F94	30-50	2-4	Sand and Gravel	S/S Clay	0-2	Silt and Clay	300-700	112
7F95	30-50	2-4	Sand and Gravel	Silty Loam	0-2	Silt and Clay	300-700	106
7F96	15-30	7-10	Sand and Gravel	Sandy Loam	0-2	Sand and Gravel	100-300	151
7F97	30-50	2-4	Sand and Gravel	S/S Clay	2-6	Silt and Clay	300-700	111



7Fb Glacial Lake Deposits over Outwash

This hydrogeologic setting consists of an area in western Fulton County in which fine-grained lacustrine deposits overlie sand and gravel outwash. This setting is characterized by flat-lying topography and low relief and lies between the Defiance Moraine and the Fort Wayne Moraine (see Fig. 5). The aquifer consists of relatively thick and continuous sand and gravel outwash deposits. Yields average 10 to 25 gpm with maximum local yields over 100 gpm. Test drilling may be necessary to locate higher-yielding areas. Vadose zone media consists of thick clayey lacustrine sediments and underlying till. These materials are sufficiently thick to be considered a confining layer. This area historically has been known for flowing wells due to these confining conditions. Depth to water is considered to be the top of the aquifer due to the confining conditions. Soils are usually shrink-swell (aggregated) clays. Soils are sandy loams or sand in areas adjacent to isolated beach ridges and dunes. Recharge is very low due to the confining conditions.

GWPP index values for the hydrogeologic setting of Glacial Lake Deposits over Outwash range from 63 to 79 with the total number of GWPP index calculations equaling 19.

Hydrogeologic Setting Values for: 7Fb- Glacial Lake Deposits over Outwash

Setting	Depth to water (ft.)	Recharge in./yr.	Aquifer Media	Soil Media	Topography % Slope	Vadose Zone Media	Hydro. Cond.	Rating
7Fb1	75-100	0-2	Sand and Gravel	S/S Clay	0-2	Confining Layer	300-700	79
7Fb2	100+	0-2	Sand and Gravel	Clay Loam	0-2	Confining Layer	300-700	63
7Fb3	100+	0-2	Sand and Gravel	Silty Loam	0-2	Confining Layer	300-700	65
7Fb4	100+	0-2	Sand and Gravel	Clay Loam	0-2	Confining Layer	300-700	66
7Fb5	75-100	0-2	Sand and Gravel	Clay Loam	0-2	Confining Layer	300-700	68
7Fb6	100+	0-2	Sand and Gravel	Silty Loam	0-2	Confining Layer	300-700	68
7Fb7	75-100	0-2	Sand and Gravel	Silty Loam	0-2	Confining Layer	300-700	70
7Fb8	100+	0-2	Sand and Gravel	S/S Clay	2-6	Confining Layer	300-700	70
7Fb9	75-100	0-2	Sand and Gravel	Clay Loam	0-2	Confining Layer	300-700	71
7Fb10	100+	0-2	Sand and Gravel	Sandy Loam	2-6	Confining Layer	300-700	71
7Fb11	100+	0-2	Sand and Gravel	S/S Clay	0-2	Confining Layer	300-700	71
7Fb12	100+	0-2	Sand and Gravel	Sandy Loam	0-2	Confining Layer	300-700	72
7Fb12	100+	0-2	Sand and Gravel	Sandy Loam	0-2	Confining Layer	300-700	72
7Fb13	75-100	0-2	Sand and Gravel	Silty Loam	0-2	Confining Layer	300-700	73
7Fb14	100+	0-2	Sand and Gravel	S/S Clay	2-6	Confining Layer	300-700	73
7Fb15	75-100	0-2	Sand and Gravel	S/S Clay	0-2	Confining Layer	300-700	79
7Fb16	100+	0-2	Sand and Gravel	S/S Clay	0-2	Confining Layer	300-700	74
7Fb18	75-100	0-2	Sand and Gravel	S/S Clay	0-2	Confining Layer	300-700	76
7Fb19	75-100	0-2	Sand and Gravel	Sandy Loam	0-2	Confining Layer	300-700	77

7H-Beaches,Beach Ridge, and Sand Dunes

This hydrogeologic setting is characterized by narrow, elongate, low-lying ridges of sand overlying the lacustrine plain or wave-planed till uplands. This setting is common to the southeastern corner and central portion of the county. The thick, laterally extensive beach / deltaic deposits in the southeastern corner and nearby Wauseon 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. In some portions of eastern Fulton County, the underlying till and lacustrine deposits are sufficiently thick to be evaluated as a confining layer. In these areas, the depth to water is great and recharge is very low. 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 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 44 to 186 with the total number of GWPP index calculations equaling 93.

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

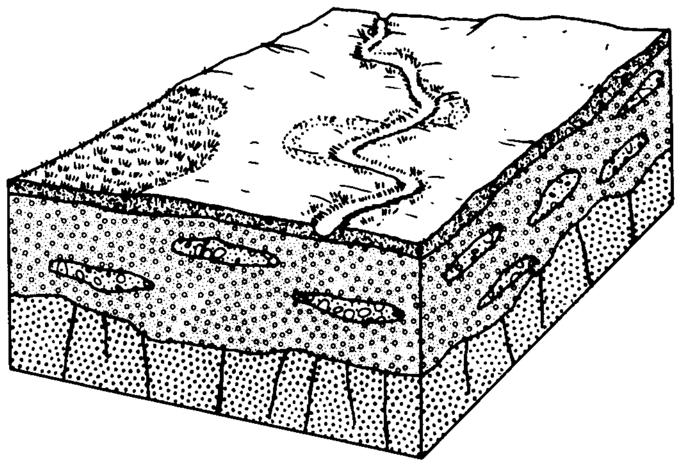
Setting	Depth to water (ft.)	Recharge in./yr.	Aquifer Media	Soil Media	Topography % Slope	Vadose Zone Media	Hydro. Cond.	Rating
7H1	100+	0-2	Massive Shale	Sandy Loam	2-6	Confining Layer	1-100	44
7H2	100+	0-2	Massive Shale	Sandy Loam	0-2	Confining Layer	1-100	45
7H3	100+	0-2	Massive Shale	S/S Clay	2-6	Confining Layer	1-100	46
7H4	100+	0-2	Massive Shale	Sand	2-6	Confining Layer	1-100	50
7H5	100+	0-2	Massive Shale	Sand	0-2	Confining Layer	1-100	51
7H6	100+	0-2	Sand and Gravel	Sandy Loam	2-6	Confining Layer	100-300	62
7H7	75-100	4-7	Massive Shale	S/S Clay	2-6	Sand and Gravel	1-100	91
7H8	100+	0-2	Sand and Gravel	Sandy Loam	0-2	Confining Layer	100-300	63
7H9	5-15	2-4	Sand and Gravel	S/S Clay	2-6	Silt and Clay	100-300	125
7H10	100+	0-2	Sand and Gravel	Sand	2-6	Confining Layer	100-300	68
7H11	75-100	2-4	Massive Shale	Sandy Loam	2-6	Silt and Clay	1-100	67
7H12	100+	0-2	Sand and Gravel	Sand	2-6	Confining Layer	100-300	68
7H13	75-100	2-4	Massive Shale	S/S Clay	2-6	Silt and Clay	1-100	69
7H14	100+	0-2	Sand and Gravel	Sand	0-2	Confining Layer	100-300	69
7H15	75-100	2-4	Massive Shale	Silty Loam	0-2	Silt and Clay	1-100	64
7H16	75-100	2-4	Massive Shale	S/S Clay	0-2	Silt and Clay	1-100	70
7H17	50-75	2-4	Massive Shale	Sandy Loam	2-6	Silt and Clay	1-100	72
7H18	30-50	2-4	Massive Shale	Silty Loam	2-6	Silt and Clay	1-100	78
7H19	75-100	2-4	Massive Shale	Sand	2-6	Silt and Clay	1-100	73
7H20	75-100	0-2	Sand and Gravel	Sand	2-6	Confining Layer	100-300	73
7H21	50-75	2-4	Massive Shale	S/S Clay	2-6	Silt and Clay	1-100	74
7H22	100+	0-2	Sand and Gravel	Sandy Loam	0-2	Confining Layer	300-700	69
7H23	100+	0-2	Sand and Gravel	Sand	2-6	Confining Layer	100-300	68
7H24	50-75	2-4	Massive Shale	S/S Clay	0-2	Silt and Clay	1-100	75
7H25	100+	0-2	Sand and Gravel	Sand	2-6	Confining Layer	300-700	74
7H26	100+	0-2	Sand and Gravel	S/S Clay	2-6	Confining Layer	300-700	76
7H27	100+	0-2	Sand and Gravel	Sand	0-2	Confining Layer	300-700	75
7H28	15-30	4-7	Sand and Gravel	Silty Loam	2-6	Sand and Gravel	300-700	142
7H29	50-75	2-4	Massive Shale	Sandy Loam	2-6	Silt and Clay	1-100	72
7H30	75-100	0-2	Sand and Gravel	S/S Clay	2-6	Confining Layer	300-700	78
7H31	75-100	0-2	Sand and Gravel	Sand	0-2	Confining Layer	300-700	80
7H32	50-75	2-4	Massive Shale	Sand	0-2	Silt and Clay	1-100	79
7H33	100+	0-2	Sand and Gravel	Sand	2-6	Confining Layer	300-700	80
7H34	30-50	2-4	Massive Shale	Sand	2-6	Silt and Clay	1-100	88
7H35	30-50	2-4	Massive Shale	Sand	0-2	Silt and Clay	1-100	89

Hydrogeologic Setting Values for: 7H-Beach Ridges and Sand Dunes (cont.)

Setting	Depth to water (ft.)	Recharge in./yr.	Aquifer Media	Soil Media	Topography % Slope	Vadose Zone Media	Hydro. Cond.	Rating
7H36	50-75	2-4	Sand and Gravel	Sandy Loam	2-6	Silt and Clay	100-300	93
7H37	50-75	4-7	Massive Shale	Sandy Loam	2-6	Sand and Gravel	1-100	94
7H38	30-50	2-4	Massive Shale	Sandy Loam	0-2	Sand and Gravel	1-100	93
7H39	30-50	4-7	Massive Shale	Silty Loam	0-2	Sand and Gravel	1-100	101
7H40	50-75	2-4	Sand and Gravel	S/S Clay	2-6	Silt and Clay	300-700	101
7H41	30-50	2-4	Sand and Gravel	S/S Clay	2-6	Silt and Clay	100-300	102
7H42	50-75	2-4	Sand and Gravel	Sand	0-2	Silt and Clay	100-300	102
7H43	50-75	4-7	Massive Shale	Sandy Loam	2-6	Sand and Gravel	1-100	104
7H44	30-50	2-4	Sand and Gravel	Sand	2-6	Silt and Clay	100-300	106
7H45	30-50	2-4	Sand and Gravel	Sand	0-2	Silt and Clay	100-300	107
7H46	30-50	2-4	Sand and Gravel	S/S Clay	2-6	Silt and Clay	300-700	108
7H47	15-30	2-4	Sand and Gravel	Loam	0-2	Silt and Clay	100-300	109
7H48	15-30	2-4	Sand and Gravel	Sandy Loam	2-6	Silt and Clay	100-300	110
7H49	30-50	2-4	Sand and Gravel	S/S Clay	2-6	Silt and Clay	300-700	111
7H50	30-50	4-7	Massive Shale	Sand	0-2	Sand and Gravel	1-100	111
7H51	30-50	2-4	Sand and Gravel	Sand	0-2	Sand and Gravel	100-300	112
7H52	15-30	2-4	Sand and Gravel	S/S Clay	0-2	Silt and Clay	100-300	113
7H53	30-50	2-4	Sand and Gravel	Sand	2-6	Sand and Gravel	100-300	116
7H54	15-30	2-4	Sand and Gravel	S/S Clay	0-2	Silt and Clay	100-300	115
7H55	50-75	4-7	Sand and Gravel	Sandy Loam	2-6	Sand and Gravel	100-300	117
7H56	15-30	2-4	Sand and Gravel	Sand	0-2	Silt and Clay	100-300	117
7H57	50-75	4-7	Sand and Gravel	S/S Clay	2-6	Sand and Gravel	100-300	119
7H59	15-30	2-4	Sand and Gravel	Sand	0-2	Sand and Gravel	100-300	122
7H60	30-50	4-7	Massive Shale	S/S Clay	0-2	Sand and Gravel	1-100	122
7H61	15-30	2-4	Sand and Gravel	S/S Clay	0-2	Sand and Gravel	100-300	123
7H62	50-75	4-7	Sand and Gravel	Sand	2-6	Sand and Gravel	100-300	123
7H63	15-30	2-4	Sand and Gravel	Sand	2-6	Sand and Gravel	100-300	126
7H64	30-50	4-7	Massive Shale	Sand	2-6	Sand and Gravel	1-100	125
7H65	5-15	2-4	Sand and Gravel	Sand	2-6	Silt and Clay	100-300	129
7H66	50-75	7-10	Sand and Gravel	Sandy Loam	2-6	Sand and Gravel	100-300	130
7H67	30-50	4-7	Sand and Gravel	Sand	0-2	Sand and Gravel	300-700	140
7H68	30-50	4-7	Sand and Gravel	S/S Clay	0-2	Sand and Gravel	300-700	131
7H69	30-50	4-7	Sand and Gravel	S/S Clay	2-6	Sand and Gravel	300-700	135
7H70	30-50	4-7	Sand and Gravel	S/S Clay	0-2	Sand and Gravel	300-700	136
7H71	50-75	4-7	Massive Shale	S/S Clay	0-2	Sand and Gravel	1-100	97
7H72	50-75	4-7	Massive Shale	Sand	0-2	Sand and Gravel	1-100	101
7H73	30-50	7-10	Sand and Gravel	Sandy Loam	2-6	Sand and Gravel	100-300	140
7H74	50-75	2-4	Sand and Gravel	Sandy Loam	0-2	Silt and Clay	300-700	100
7H75	15-30	4-7	Sand and Gravel	Sand	2-6	Sand and Gravel	100-300	143

Hydrogeologic Setting Values for: 7H-Beach Ridges and Sand Dunes (cont.)

Setting	Depth to water (ft.)	Recharge in./yr.	Aquifer Media	Soil Media	Topography % Slope	Vadose Zone Media	Hydro. Cond.	Rating
7H76	15-30	4-7	Sand and Gravel	Sand	0-2	Sand and Gravel	100-300	144
7H77	15-30	4-7	Sand and Gravel	Sandy Loam	2-6	Sand and Gravel	300-700	146
7H78	15-30	4-7	Sand and Gravel	Sandy Loam	0-2	Sand and Gravel	300-700	147
7H79	15-30	7-10	Massive Shale	Sandy Loam	0-2	Sand and Gravel	1-100	128
7H80	5-15	10+	Sand and Gravel	Gravel	2-6	Sand and Gravel	100-300	172
7H81	5-15	10+	Sand and Gravel	Sandy Loam	0-2	Sand and Gravel	100-300	165
7H82	5-15	10+	Sand and Gravel	Sand	2-6	Sand and Gravel	100-300	170
7H83	5-15	10+	Sand and Gravel	Sand	0-2	Sand and Gravel	100-300	171
7H84	0-5	7-10	Sand and Gravel	S/S Clay	2-6	Sand and Gravel	300-700	184
7H85	0-5	7-10	Sand and Gravel	Sand	0-2	Sand and Gravel	300-700	186
7H86	0-5	7-10	Sand and Gravel	Sand	2-6	Sand and Gravel	300-700	185
7H87	15-30	7-10	Sand and Gravel	Sandy Loam	0-2	Sand and Gravel	300-700	167
7H88	15-30	7-10	Sand and Gravel	S/S Clay	0-2	Sand and Gravel	300-700	167
7H89	5-15	4-7	Sand and Gravel	Sand	0-2	Sand and Gravel	300-700	173
7H90	5-15	4-7	Sand and Gravel	Sand	2-6	Sand and Gravel	300-700	172
7H91	50-75	4-7	Sand and Gravel	Silty Loam	0-2	Sand and Gravel	100-300	109
7H92	5-15	4-7	Sand and Gravel	S/S Clay	2-6	Sand and Gravel	300-700	168
7H93	30-50	4-7	Massive Shale	Sandy Loam	2-6	Sand and Gravel	1-100	104



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 two low, depress ional areas flanked by coarser-grained deposits. Beach ridge deposits associated with the Oak Openings encircle the larger area. These deposits border Henry 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.

GWPP index values for the hydrogeologic setting of Marshes and Swamps range from 151 to 173 with the total number of GWPP index calculations equaling 2.

Hydrogeologic Setting Values for: 7I-Marshes and Swamps

Setting	Depth to water (ft.)	Recharge in./yr.	Aquifer Media	Soil Media	Topography % Slope	Vadose Zone Media	Hydro. Cond.	Rating
7I1	15-30	4-7	Sand and Gravel	Peat	0-2	Sand and Gravel	300-700	151
7I2	5-15	10+	Sand and Gravel	Gravel	0-2	Sand and Gravel	100-300	173