GROUND WATER POLLUTION POTENTIAL
OF PUTNAM COUNTY, OHIO

BY

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ABSTRACT

A ground water pollution potential map of Putnam 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 Putnam County resulted in a map with symbols and colors, which illustrate areas of varying ground water pollution potential indexes ranging from 95 to 159.

Putnam County lies entirely within the Glaciated Central hydrogeologic setting. Limestones and dolomites of the Silurian System compose the aquifer for most of the county. Thin Devonian-age limestones and dolomites are found along the northern fringe of the county. Yields in the uppermost carbonate aquifers range from 5 to 100 gallons per minute (gpm) for most of the county. Yields over 100 gpm are possible for almost the entire county from larger diameter wells drilled deeper into the limestone.

Deep layers of sand and gravel are utilized as the aquifer in the main trunk of the deep buried valley system found in southwestern Putnam County. These buried valleys are tributaries of the ancient Teays River valley system. Yields over 100 gpm are possible from properly designed large diameter wells completed in these deeper units. Wells yielding 5 to 25 gpm can be obtained from sand and gravel lenses interbedded with fine-grained glacial till or lacustrine (lake) deposits overlying these deeper sand and gravel deposits. These wells are suitable for domestic and farm purposes.

Outside of the buried valley system, small sand and gravel lenses interbedded in the glacial till locally serve as aquifers in isolated portions of Putnam County. Yields for these sand and gravel lenses range from 5 to 25 gpm. The sand and gravel lenses may lie directly on top of the limestone bedrock and serve as the aquifer, or provide additional recharge to the underlying bedrock.

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 Putnam County has been prepared to assist planners, managers, and local officials in evaluating the potential for contamination from various sources of pollution. This information can be used to help direct resources and land use activities to appropriate areas, or to assist in protection, monitoring, and clean-up efforts.

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For her 1992 Master's thesis, Cynthia M. Wurm of Bowling Green State University completed a preliminary ground water pollution potential map for Putnam County using geographical information system (GIS) and the DRASTIC system. Her work proved to be a helpful guideline in determining ratings, and serves as an early example of GIS use in Ohio.

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INTRODUCTION

The need for protection and management of ground water resources in Ohio has been clearly recognized. Approximately 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; 6,000 of these wells exist in Putnam 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 remediation 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 countywide 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 Putnam 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

DRASTIC was developed by the National Ground Water Association for the United States Environmental Protection Agency. This system was chosen for implementation of a ground water pollution potential mapping program in Ohio. 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 Putnam 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

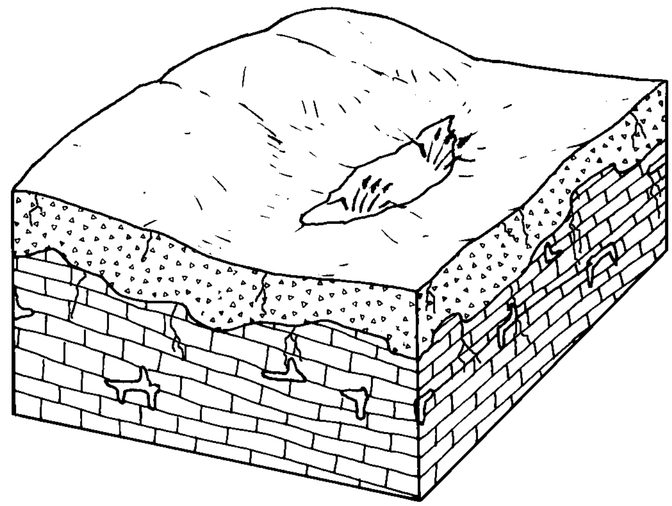
These factors incorporate concepts and mechanisms such as attenuation, retardation, and time or distance of travel of a contaminant with respect to the physical characteristics of the hydrogeologic setting. Broad consideration of these factors and mechanisms coupled with existing conditions in a setting 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.

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.



7Ac-Glacial Till over Limestone

This hydrogeologic setting is limited to portions of southeastern Putnam County. These areas represent the only portions of the ground moraine that were at a high enough elevation not to be eroded by ancestral Lake Maumee. The area is characterized by flat-lying topography and low relief. The vadose zone consists primarily of silty to clayey glacial till. The till may be fractured or jointed, particularly in areas where it is predominantly thin and weathered. Where the till is very thin, fractured limestone is considered to be the vadose zone media together with the till. The aquifer is composed of fractured Silurian limestones and dolomites. These carbonate rocks may contain significant solution features. Depth to water is usually shallow, ranging from 15 to 30 feet. Soils typically are clay loams derived from till. Maximum ground water yields greater than 100 gpm are possible from the Silurian Lockport, Tymochtee, Greenfield and Salina Groups. Recharge is moderate due to the clayey nature of the soils and vadose zone and the relatively shallow depth to water and permeable nature of the bedrock aquifer. Recharge rates increase somewhat where the limestone bedrock is closer to the ground surface.

GWPP index values for the hydrogeologic setting of Glacial Till over Limestone range from 133 to 152, with the total number of GWPP index calculations equaling 4.

Figure 1. Format and description of the hydrogeologic setting – 7Ac Glacial Till over Limestone.

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

Table 2. Ranges and ratings for depth to water

Depth to Water (feet)	
Range	**Rating**
0-5	10
5-15	9
15-30	7
30-50	5
50-75	3
75-100	2
100+	1
Weight: 5	Pesticide Weight: 5

Table 3. Ranges and ratings for net recharge

Net Recharge (inches)	
Range	**Rating**
0-2	1
2-4	3
4-7	6
7-10	8
10+	9
Weight: 4	Pesticide Weight: 4

Table 4. Ranges and ratings for aquifer media

Aquifer Media		
Range	**Rating**	**Typical Rating**
Shale	1-3	2
Glacial Till	4-6	5
Sandstone	4-9	6
Limestone	4-9	6
Sand & gravel	4-9	8
Interbedded Ss/Sh/Ls/Coal	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/Absent	10
Gravel	10
Sand	9
Peat	8
Shrink/Swell Clay	7
Sandy Loam	6
Loam	5
Silty Loam	4
Clay Loam	3
Muck	2
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
Interbedded Ss/Sh/Ls/Coal	4-8	6
Sand & gravel with Silt and Clay	4-8	6
Glacial Till	2-6	4
Sand & gravel	6-9	8
Karst Limestone	8-10	10
Weight: 5	Pesticide Weight: 4	

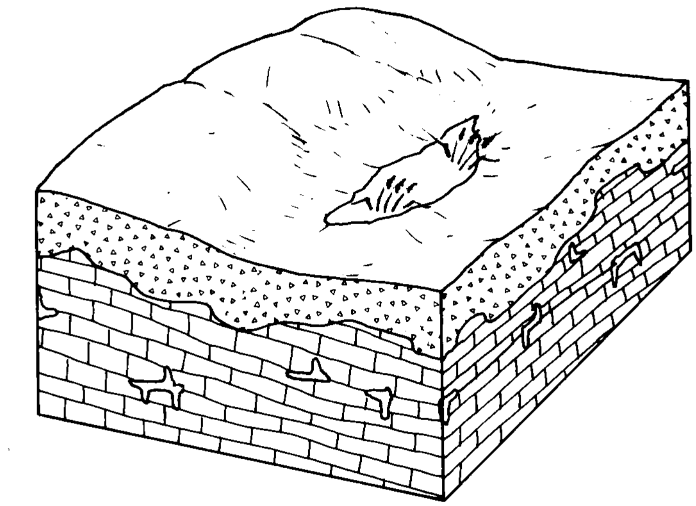
Table 8. Ranges and ratings for hydraulic conductivity

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 7Ac1, Glacial Till over Limestone, identified in mapping Putnam 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 133. 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 Putnam County produces settings with a wide range of vulnerability to ground water contamination. Calculated pollution potential indexes for the nine settings identified in the county range from 95 to 159.

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 Putnam 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 Putnam County is included with this report.



SETTING 7Ac1		GENERAL		
FEATURE	**RANGE**	**WEIGHT**	**RATING**	**NUMBER**
Depth to Water	15-30	5	7	35
Net Recharge	4-7	4	6	24
Aquifer Media	Limestone	3	7	21
Soil Media	Clay Loam	2	3	6
Topography	0-2 %	1	10	10
Impact of Vadose Zone	Till	5	5	25
Hydraulic Conductivity	300-700	3	4	12
		DRASTIC	INDEX	133

Figure 2. Description of the hydrogeologic setting – 7Ac1 Glacial Till over Limestone.

INTERPRETATION AND USE OF GROUND WATER POLLUTION POTENTIAL MAPS

The application of the DRASTIC system to evaluate an aquifer's vulnerability to contamination produces hydrogeologic settings with corresponding pollution potential indexes. The susceptibility to contamination is greater as the pollution potential index increases. 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:

7Ac1 - defines the hydrogeologic region and setting
133 - defines the relative pollution potential

The first number (**7**) refers to the major hydrogeologic region and the upper case letter and lower case letter (**Ac**) refers 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 (**133**) 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 maps also delineate large man-made and natural features such as lakes, landfills, quarries, and strip mines, but these areas are not rated and therefore are not color-coded.

GENERAL INFORMATION ABOUT PUTNAM COUNTY

Demographics

Putnam County occupies approximately 486 square miles (Brock and Urban, 1974) in north central Ohio (Figure 3). Putnam County is bounded to the east by Hancock County, to the southwest by Van Wert County, to the north by Henry and Defiance Counties, to the northwest by Paulding County, and to the south by Allen County.

The approximate population of Putnam County, based upon year 2004 census estimates, is 34,718 (Department of Development, Ohio County Profiles, 2005). Ottawa is the largest community and the county seat. Agriculture accounts for roughly 94 percent of the land usage in Putnam 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).

Climate

The *Hydrologic Atlas for Ohio* (Harstine, 1991) reports an average annual temperature of approximately 50 to 51 degrees Fahrenheit for Putnam County. Harstine (1991) shows that precipitation approximately averages 34 to 35 inches per year for the county. The mean annual precipitation for Ottawa is 33.7 inches per year based upon a thirty-year (1971-2000) period (National Oceanographic and Atmospheric Administration (NOAA), 2002). The mean annual temperature at Ottawa for the same thirty-year period is 51.1 degrees Fahrenheit (NOAA, 2002).

Physiography and Topography

The vast majority of Putnam County lies within the Lake Plains Province, while the southeastern corner of the county lies within the Central Till Plains Province (Frost, 1931, Fenneman, 1938, and Bier, 1956). Brockman (1998) and Schiefer (2002) depict the southeastern corner of Putnam County as belonging in the Central Ohio Clayey Till Plain. The remainder of the county is part of the Maumee Lake Plains. The northwestern part of Putnam County belongs to a subsection of the Maumee Lake Plains referred to as the Paulding Clay Bottom, known for its very fine-grained soils and sediments (Brockman, 1998 and Schiefer, 2002). Part of eastern Putnam County belongs to the Fostoria Lake-Plains Shoals (Brockman, 1998 and Schiefer, 2002), an area marked by beach ridges and portions of the Defiance End Moraine. Flat lake plains characterize Putnam County. Gentle beach ridges and the subdued western edge of the Defiance Moraine provide modest relief.

Figure 3. Location map of Putnam County, Ohio.

Modern Drainage

Putnam County lies north of the major drainage divide crossing north central Ohio; all of Putnam County drains toward Lake Erie. The majority of the county drains into the Auglaize River, either directly or through tributaries. The Auglaize River directly drains the southwestern portion of the county. The Ottawa River and Plum Creek are important tributaries, draining southern Putnam County. The Blanchard River drains much of eastern and central Putnam County, and joins the Auglaize River south of Continental. Two tributaries of the Blanchard River, Cranberry Creek and Riley Creek, drain southeastern Putnam County. Powell Creek drains northwestern Putnam County, flowing northward before joining the Auglaize River in the city of Defiance. Northeastern Putnam County is drained by a number of small tributaries that flow northward and eventually directly empty into the Maumee River in Henry County.

Pre- and Inter-Glacial Drainage Changes

The drainage patterns of Putnam County have changed significantly as a result of the multiple glaciations. The drainage changes are complex and not yet fully understood. More research and data are necessary in both Putnam County and adjacent counties. Particularly, well log data for deeper wells that penetrate the entire drift thickness would be helpful in making interpretations. This would allow a more accurate reconstruction of the system of buried valleys and former drainage channels for the county.

Prior to glaciation, the drainage in Ohio is referred to as the Teays Stage. The Teays River drained the southern and western two thirds of the state and was the master stream for what is now the upper Ohio River Valley. Drainage in southern Putnam County was to the south, towards the Teays River. Stout et al. (1943) referred to a large, southwesterly-flowing tributary that drained Allen County and southern Putnam County as Wapakoneta Creek (Figure 4). Modern bedrock topography data (Kostelnick, 1981 and Open File Bedrock Topography Maps, ODNR, Division of Geological Survey) show a deep, Y-shaped channel extending across southwestern Putnam County. The eastern branch of the Y extends to the northeast towards Ottawa and roughly lies between the villages of Kalida to the north and Columbus Grove to the south. The western branch of the Y trends toward the junction of Putnam, Paulding, and Van Wert Counties and roughly lies between Ottoville and Fort Jennings to the south and Kalida to the north.

Stout et al (1943) showed the drainage divide between the Teays River and the ancestral Lake Erie basin as roughly passing from east to west through central Putnam County. Stuckey (1988) speculated that the divide may be due to a number of resistant limestone highs found in east central Putnam County. Northern Putnam County drained to the north, possibly flowing to the Napoleon River, an ancestor to the Maumee River flowing through Henry County.

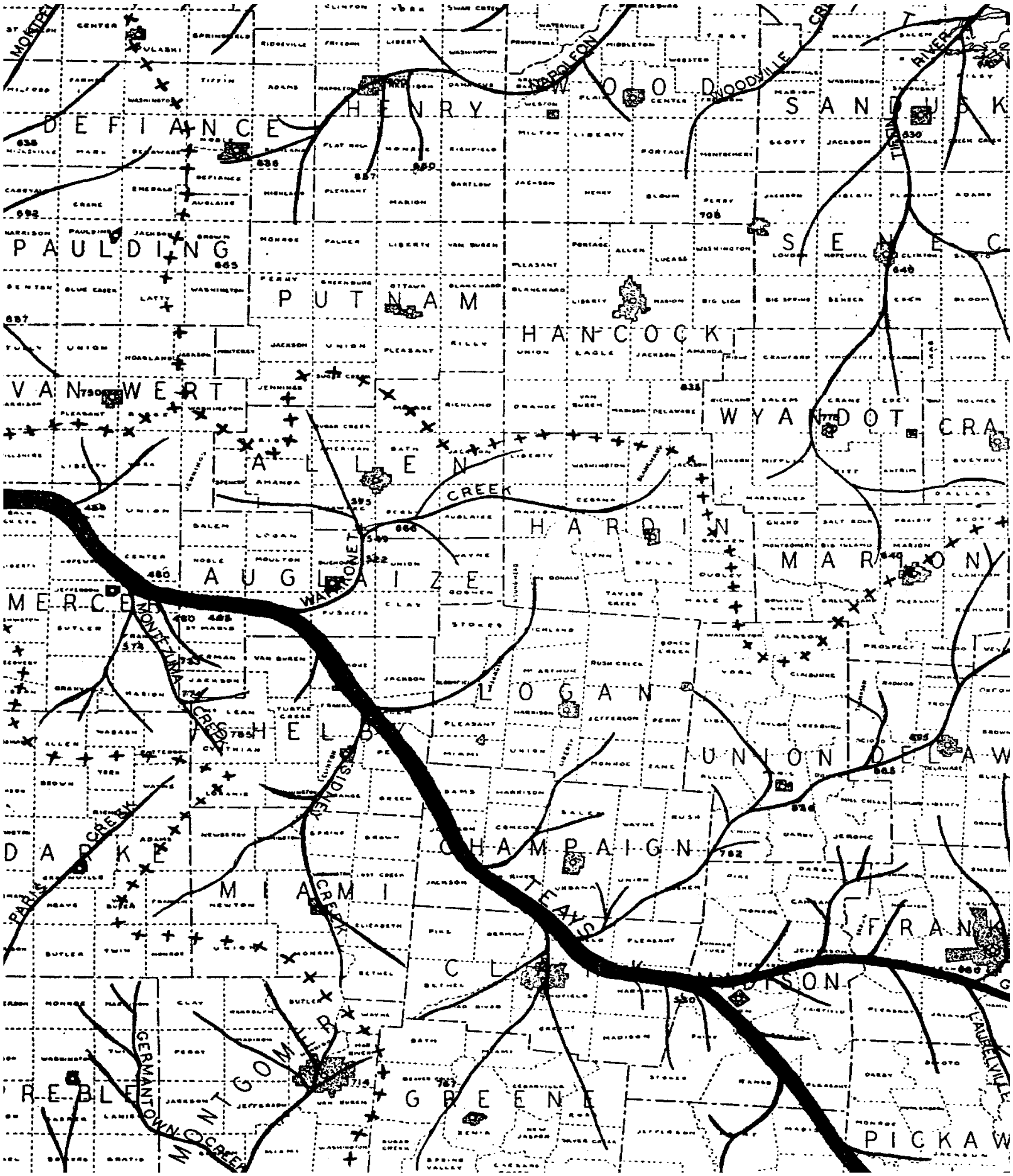


Figure 4. Teays Stage drainage in Putnam County (after Stout et al., 1943).

As ice advanced through Ohio during the pre-Illinoian (Kansan) glaciations, drainage ways to the north and west were blocked. The pre-existing channels and valleys created by the Teays River drainage system were overrun by the advancing glaciers and filled with glacial till from the advancing ice sheets. Subsequent ice advances during the Illinoian and Wisconsinan ice advances further filled these former channels. These sediment-filled ancestral valleys are referred to as buried valleys. Slowly the drainage patterns of Putnam County evolved and drainage shifted towards the north during ice-free intervals. The modern drainage reflects the nature of landforms deposited during the Wisconsinan advances, particularly the Lake Maumee basin.

Glacial Geology

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

The unconsolidated (glacial) deposits in Putnam County fall into four main types: (glacial) till, lacustrine deposits, beach/deltaic/dune deposits, alluvial (river) deposits, and ice-contact sand and gravel (kames, eskers) deposits. Alluvium consists of both ancestral and modern sediments deposited by rivers. Drift is an older term that collectively refers to the entire sequence of glacial deposits. Overall, drift is thinner in areas of ground moraine and thickens with the Defiance End Moraine just south of Leipsic. It is thickest in the narrow buried valleys associated with the Teays River System in southwestern Putnam County. Throughout the southern third of the county, drift is usually thin (less than 25 ft), and the bedrock is close to the ground surface (ODNR, Division of Geological Survey, Open File Bedrock Topography and ODNR, Division of Water, Glacial State Aquifer Map, 2000). These areas typically correspond to where wave activity associated with ancestral Lake Maumee eroded much of the pre-existing ground moraine away.

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 and ablation tills. 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 or 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. This process can happen at the top or at the bottom of the glacier. 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-rich environment in Putnam County. These types of tills are associated with ancestral Lake Maumee, and were deposited through the floating and grounding actions of a relatively thin ice sheet. The water level of the lake and thickness of the ice sheet would influence such actions. As a result, these tills may more closely resemble lacustrine deposits (Forsyth, 1965).

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. (Brockman and Szabo, 2000 and Haefner, 2000). Fractures may also interconnect sand and gravel lenses.

At the land surface, till accounts for two primary landforms: ground moraine and end moraine. Ground moraine (till plain) is relatively flat to gently rolling. The flatness of the ground moraine in Putnam County has been accentuated by erosion by waves in the shallow ancestral lakes. The ground moraine may be referred to in Putnam County as "wave-eroded till plain". End moraines are ridge-like, with terrain that is steeper and more rolling or hummocky. End moraines commonly serve as a local drainage divide due to their ridge-like nature. End moraines also locally account for an overall thickening of the till. End moraines in Putnam County are limited to a short spur of the Defiance End Moraine just south of the village of Leipsic. It appears Lake Maumee probably covered or "drowned" the moraine at one time.

Alluvial deposits are sediments deposited by either the floodplain or channel of rivers and streams. As modern streams downcut, the older, now higher elevation remnants of the original valley floor are called terraces. Terraces in Putnam County tend to be relatively low elevation and are at elevations just above the current floodplain. Alluvium will vary in nature from fine sand to silty-sand to clayey silt.

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. The resulting land surface is flat, gently sloping towards the Maumee River and Lake Erie. 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 in situ 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.

In Putnam County, only the extreme southeast corner lies at an elevation above the Lake Maumee Plain. This area represents more typical ground moraine. The remainder of the county is roughly split between areas with wave-planed glacial till at the surface or areas with fine-grained lacustrine silt and clay at the surface. Both materials are especially clayey.

There is an area of flat lake plain in southeastern Putnam County where the surficial soils are silty lacustrine and might reflect local deposition on a past deltaic environment.

The beach levels Putnam County are associated with a number of the ancestral lakes. The sequence of ancestral lake levels and elevations of beaches in Putnam County are listed in Table 9. Forsyth (1959 and 1973) gives a detailed discussion of the beach levels and lake history in northwestern Ohio. Beach ridges for the Lower and Middle Maumee (755 and 775 feet respectively) and the Whittlesey (735 feet) are fairly prominent in Putnam County. Middle Maumee beach ridges tend to wrap around the Defiance End Moraine. There are some minor remnants of the Upper Arkona beach ridge in north central Putnam County. 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.

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

Table 9. Sequence of ancestral lake levels and beaches in Putnam County (after Forsyth, 1959 and 1973).

Lake Stage	Age (Years B.P.)	Elevation (ft.)	Outlet	Found in Putnam 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.	No
Wayne		655-660	Grand River, Mi or Mohawk River, N.Y.	No
Upper Warren	<13,000	685-690	Grand River, Mi.	No
Whittlesey	>13,000	735	Grand River, Mi	Yes
Lower Arkona		700-705	Grand River, Mi	No
Upper Arkona		715-720	Grand River, Mi	Yes
Middle Maumee	14,000	775-780	Wabash River, In	Yes
Lower Maumee		755	Grand River, Mi	Yes
Upper Maumee		800	Wabash River, In	No

Bedrock Geology

Silurian limestone and dolomite underlies the surface of the majority of Putnam County. Thin Devonian limestones and dolomites underlie the surface along the northernmost fringe of Putnam County. Table 10 summarizes the bedrock stratigraphy found in Putnam County. The ODNR, Division of Geological Survey has Open-File Reconnaissance Bedrock Geology Maps completed at a 1:24,000 scale on USGS topographic map bases available for the entire county. The ODNR, Division of Water has Open File Bedrock State Aquifer maps available for the county also.

The youngest units encountered in Putnam County are the Devonian Traverse Group, Dundee Limestone, and Detroit River Group. These units consist of alternating sandy, cherty, and shaley limestones and dolomites. They formed in variable depths of water in warm seas. These units are limited to the northernmost fringe of Putnam County.

Table 10. Bedrock stratigraphy of Putnam County

System	Group/Formation (Symbol)	Lithologic Description
Devonian	Traverse Group, Dundee Limestone, Detroit River Group (Dtddr)	Gray to brown thin limestones and dolomites. Basal part includes sandy zones. Also may have shaley, cherty, and fossiliferous zones and have some evaporite bands. Yields typically in the 5 to 25 gpm range, lower where units are thin.
Silurian	Undifferentiated Salina Dolomite (Sus)	Gray to brown, thin-bedded, argillaceous dolomite. Thin evaporite zones common. Thickness and yield decrease toward the south, especially along margins of the buried valleys. Yields typically in the 5 to 25 gpm range, may exceed 25 gpm when fractures or solution features are encountered.
	Tymochtee and Greenfield Dolomites (Stg)	Thin- to massive-bedded, olive-gray to yellowish-brown. The Tymochtee contains shale partings. The Greenfield has a laminated dolomite lithology. Thickness decreases along margins of buried valleys. Maximum yields average 25 to 100 gpm across the county. Yields can be >100 gpm, especially in the central portion of the county.
	Lockport Dolomite (Sl)	White to medium gray, medium- to massive-bedded dolomite. Commonly contains cavernous solution zones. Thickness >100 feet. Yields can exceed 100 gpm, especially in cavernous or solution zones. Yield and thickness are relatively consistent across the county.

The youngest Silurian unit is the Salina Undifferentiated Group, which consists of dolomites, fine-grained limestones, and some minor evaporite deposits such as gypsum. These rocks were deposited in warm, shallow tidal areas. Units of the Salina Undifferentiated Group tend to thin to the south. Thickness of this formation decreases along the margins of the deep buried valley system in southwestern Putnam County.

Underlying the Salina Undifferentiated Group are rocks of the Silurian Tymochtee and Greenfield Formations, which were also deposited in warm, shallow seas. These two formations tend to become thinner along the margins of the deep buried valley system in southwestern Putnam County.

The oldest unit typically encountered by water wells is the Silurian Lockport Group. Rocks of the Lockport are commonly found in the subsurface across Putnam County. These rocks become progressively deeper to the north. The Lockport Group rocks were associated with tidal reefs deposited in warm, high-energy shallow seas.

Ground Water Resources

Ground water in Putnam County is obtained from both unconsolidated (glacial-alluvial) and consolidated (bedrock) aquifers. Stuckey (1988) gives a detailed account of ground water resources in Putnam County. Deep layers of sand and gravel are utilized as the aquifer in the main trunk of the deep buried valley system found in southwestern Putnam County.

Well yields exceeding 100 gpm are possible from properly designed large diameter wells completed in these deeper units (ODNR, Div. of Water, 1970 and Calhoun, 1992). Wells yielding 5 to 25 gpm can be obtained from sand and gravel lenses interbedded in the overlying fine-grained glacial till or lacustrine (lake) deposits. These wells are suitable for domestic and farm purposes.

Thin lenses of sand and gravel interbedded with till comprise the glacial aquifers for a limited number of areas in northern Putnam County. The sand and gravel lenses may directly overlie the carbonate bedrock. These lenses may serve as an aquifer or, more commonly, serve as an extra source of recharge to the underlying fractured bedrock. Well drillers may penetrate the bedrock directly below the sand and gravel to complete the well. In such cases the bedrock acts as a "screen" to help filter fines out of the gravel. Lenses of sand and gravel found interbedded with the thick till associated with the Defiance Moraine (Calhoun, 1992) provide adequate yields for domestic wells in the vicinity of Leipsic.

The carbonate aquifer is an important regional aquifer for most of northwestern and north central Ohio and underlies all of Putnam County (ODNR, Div. of Water, 1970 and Calhoun, 1992). Completed water wells typically penetrate multiple bedrock units. Yields exceeding 100 gpm are available from deep, large diameter wells drilled into the Silurian Tymochtee and Greenfield Dolomites in central Putnam County, and from the Lockport Dolomite throughout the county (ODNR, Div. of Water, Open File, Bedrock State Aquifer Map, 2000, ODNR, Div. of Water, 1970, and Calhoun, 1992). In areas along the margins of the buried valleys, the thicknesses of the Salina Undifferentiated Group and the Tymochtee and Greenfield Dolomites decrease appreciably, and their yields drop correspondingly. However, higher yields may still be obtained by completing the wells deeper into the Lockport Dolomite. The assumption that a deeper well will always produce higher yields is a generalization. The amount of fracturing, solution, and vuggy (porous) zones has great local importance. Studies by Raab and Jones (1989) and Eagon & Assoc. (1997) showed the importance of localized preferred orientation of fractures on depth to water, drawdown, and the cone of depression during heavy pumping. Deeper wells are more likely to contain highly mineralized water and have objectionable water quality.

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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). Approximately 6,000 water well log records are on file for Putnam County. Data from roughly 3,144 located water well log records were analyzed and plotted on U.S.G.S. 7-1/2 minute topographic maps during the course of the project. Static water levels and information as to the depths at which water was encountered were taken from these records. The *Ground Water Resources of Putnam County* (Calhoun, 1992) provided generalized depth to water information throughout the county. Depth to water values from the preliminary DRASTIC map for Putnam County thesis by Wurm (1992) was used as a guide. Stuckey (1988) had a generalized potentiometric surface map for Putnam County that was very useful in determining relative depths to water across the county. Generalized regional depth to water information was obtained from the ODNR, Division of Water (1970) report. Depth to water trends mapped in adjoining Hancock County (Smith, 1994), Allen County (Angle and Barrett, 2005), Wood County (Smith and Sabol, 1994), and Henry County (Miller et al., 2002) served as a guideline. Localized studies providing information on the depth to water included Raab and Jones (1989), and Eagon & Associates (1997). Trends noted in these areas could be extrapolated to surrounding areas. Topographic and geomorphic trends were utilized in areas where other sources of data were lacking.

Depths to water of 5 to 15 feet (9) were selected for most of the alluvial settings in Putnam County. Depths to water of 5 to 15 feet (9) were also common in the areas of thin drift (shallow to bedrock) found in southern Putnam County. Depths to water of 15 to 30 feet (7) were used for most areas of the lake plain in western Putnam County. Depths to water of 30 to 50 feet (5) were utilized for areas with thicker glacial drift in north central and northeastern Putnam County. Depths to water of 50 to 75 feet (3) were used mostly for 7C-Moraine settings associated with areas of the Defiance Moraine in the northeastern part of the county. These areas tended to have a fairly thick cover of glacial till over the limestone bedrock aquifer.

Net Recharge

Recharge is the precipitation that reaches the aquifer. 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), Stuckey (1988), and Dumouchelle and Schiefer (2002) proved to be helpful. Recharge values from the preliminary DRASTIC map for Putnam County thesis by Wurm (1992) were used as a guide. Recharge ratings from neighboring Hancock County (Smith, 1994), Allen County (Angle and Barrett, 2005), Wood County (Smith and Sabol, 1994), and Henry County (Miller et al, 2002) served as a guideline.

Values of 4 to 7 inches per year (6) were used for areas with moderate recharge. This includes southern and most of western Putnam County. It includes all of the 7Ec – Alluvium over Sedimentary Rocks and 7H-Beaches, Beach Ridges, and Sand Dunes setting throughout the county. Drift thickness was determined to be a critical factor in determining recharge. The importance of drift thickness was emphasized by the theses of Stuckey (1988) and Wurm (1992). Areas overlain by more than 50 feet of clayey till or lacustrine sediments were determined to have recharge values ranging from 2 to 4 inches per year (3). This range of recharge values was selected for northern Putnam County, particularly in the areas associated with the Defiance Moraine.

Aquifer Media

Information on evaluating aquifer media was obtained from the *Ground Water Resources of Putnam County* (Calhoun, 1992). 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. Aquifer media ratings from the preliminary DRASTIC map for Putnam County thesis by Wurm (1992) were used as a guide. Aquifer media ratings from neighboring Hancock County (Smith, 1994), Allen County (Angle and Barrett, 2005), Wood County (Smith and Sabol, 1994), and Henry County (Miller et al., 2002) served as a guideline. The ODNR, Division of Water, Glacial State Aquifer Map (2000) and Bedrock State Aquifer Map (2000) were an important source of aquifer data. The *Glacial Map of Ohio* (Goldthwait et al., 1961), and the *Quaternary Geology of Ohio* (Pavey et al., 1999) provided useful information on the nature of the glacial aquifers and the delineation of the hydrogeologic settings. Additional information on limestone aquifers was obtained from a report (Division of Water, 1970) on carbonate rocks in northwestern Ohio. The thesis of Stuckey (1988) provided useful aquifer information, as did the study of Eagon & Associates (1997). Well log records on file at the ODNR, Division of Water, were the primary source of aquifer information.

All of the bedrock and most of the interbedded lenses of sand and gravel are semi-confined or leaky; though, for the purposes of DRASTIC, they have been evaluated as being unconfined (Aller et al., 1987). Limestone was evaluated as the aquifer for the majority of Putnam County. A rating of (7) was applied to all have the Silurian and Devonian limestone aquifers in Putnam County. Some of the yields of the upper bedrock aquifers seemed lower in eastern Putnam County; however, more typical, relatively high yields could be obtained at greater depths almost anywhere in the county.

Sand and gravel was evaluated as the aquifer along the buried valleys that reflect the tributaries of the ancestral Teays River System. Sand and gravel in these 7D-Buried Valley settings were assigned an aquifer rating of (7). The remaining unconsolidated aquifers consist of small, isolated areas of thin sand and gravel lenses. These sand and gravel lenses are interbedded within the much thicker sequence of fine-grained till or lacustrine sediments, and were given an aquifer rating of (6). Yields and drawdown data reported on water well log records were also used to help evaluate the sand and gravel deposits.

Soils

Soils were mapped using the data obtained from the *Soil Survey of Putnam County* (Brock and Urban, 1974). Each soil type was evaluated and given a rating for soil media. Evaluations were based upon the texture, permeability, and shrink-swell potential for each soil material. Special emphasis is placed upon determining the most restrictive layer. The soils of Putnam 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 Putnam County.

Soils were considered to be sand (9) for a very limited number of areas in southeastern Putnam County where fine-grained sand dunes capped the beach ridges. Shrink-swell (non-aggregated) clays (7) were selected for the highly clayey soils found at the surface of the 7Fd-Wave-eroded Lake Plain and the 7F-Glacial Lake Deposits settings. Shrink-swell clays are the most common soils mapped in the county. These soils were formed on the water-eroded till and lacustrine sediments associated with ancestral Lake Maumee. Sandy loam (6) soils were associated with sandy sediments found in the 7H-Beaches, Beach Ridges, and Sand Dunes setting. Sandy loam (6) soils were also found on a few terraces and along a limited number of areas adjacent to end moraines. Loam (5) soils were selected for a number of areas where the surficial deposits had an intermediate texture soil. These areas included thin layers of fine sand that had been eroded off beach ridges and in areas with coarser alluvial deposits. Loam soils (5) also occupy much of the southern side of the Defiance Moraine and perhaps indicate an area of eroded ablation or melt-out till. Silt loam (4) was designated for silty, finer-grained alluvial and floodplain deposits. Silt loam (4) was also used for an area of southeastern Putnam County overlain by silty deltaic sediments. Clay loam (3) soils were evaluated for areas of ground moraine occupying elevations above the lake plain. These areas of ground moraine have till at the surface that was not modified by lacustrine processes and are limited to southeastern Putnam County.

Topography

Topography, or percent slope, was evaluated using U.S.G.S. 7-1/2 minute quadrangle maps and the *Soil Survey of Putnam County* (Brock and Urban, 1974). Slopes of 0 to 2 percent (10) were widespread in Putnam County including areas of 7Fd-Wave-eroded Lake Plain and 7F-Glacial Lake Deposits settings, alluvial and floodplain deposits, and flatter-lying portions of ground moraine. Slopes of 2 to 6 percent (9) were limited to the Defiance Moraine and to some dissected, sloping areas adjacent to the Blanchard River.

Table 11. Putnam County soils

Soil Name	Parent Material/ Setting	DRASTIC Rating	Soil Media
Arkport	Beach ridges, dunes	9	Sand
Belmore	Beach ridges	6	Sandy loam
Blount	Clayey till	3	Clay loam
Broughton	Clayey lacustrine slopes along streams	7	Shrink-swell clay
Colwood	Fine beach, deltaic	5	Loam
Defiance	Clayey alluvium	7	Shrink-swell clay
Del Rey	Silty-clayey lacustrine	3	Clay loam
Digby	Beach ridge	6	Sandy loam
Fulton	Clayey lacustrine	7	Shrink-swell clay
Genesee	Alluvium	4	Silt loam
Haney	Beach ridge	5	Loam
Haskins	Beach sand over till	5	Loam
Hoytville	Wave-planed till	7	Shrink-swell clay
Kibbie	Fine deltaic sand	5	Loam
Latty	Clayey lacustrine	7	Shrink-swell clay
Lenawee	Silty lacustrine, deltaic	4	Silt loam
Lucas	Clayey lacustrine	7	Shrink-swell clay
Mermill	Very thin sand over clayey lacustrine	7	Shrink-swell clay
Milgrove	Thin outwash over till	5	Loam
Morley	Clayey till	3	Clay loam
Nappanee	Water-modified till	7	Shrink-swell clay
Ottokee	Sandy cap on beaches, dunes	9	Sand
Paulding	Clayey lacustrine	7	Shrink-swell clay
Rawson	Thin beach sand over lacustrine	5	Loam
Rimer	Beach ridge, dune	6	Sandy Loam
Roselms	Clayey lacustrine	7	Shrink-swell clay
St. Clair	Clayey lacustrine	7	Shrink-swell clay
Seward	Thin beach, deltaic over till	5	Loam
Shinrock	Very thin sand over lacustrine	7	Shrink-swell clay
Shoals	Alluvium	4	Silt loam
Sloan	Alluvium	4	Silt loam
Tedrow	Beach ridges, dunes	6	Sandy loam
Toledo	Clayey lacustrine	7	Shrink-swell clay
Tuscola	Deltaic, fine beach ridge	5	Loam
Vaughnsville	Thin sand over clayey till	7	Shrink-swell clay
Wabasha	Alluvium composed of lake sediments	7	Shrink-swell clay
Wauseon	Thin sand over clayey till	7	Shrink-swell clay
Willette	Muck, peat, bog	8	Peat

Impact of the Vadose Zone Media

Information on evaluating vadose zone media was obtained primarily from the *Ground Water Resources of Putnam County* (Calhoun, 1992) and water well log records on file at the ODNR, Division of Water. 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. Vadose zone media ratings from the preliminary DRASTIC map for Putnam County thesis by Wurm (1992) were used as a guide. Vadose zone media ratings from neighboring Hancock County (Smith, 1994), Allen County (Angle and Barrett, 2005), Wood County (Smith and Sabol, 1994), and Henry County (Miller et al., 2002) served as a guideline. The thesis of Stuckey (1988) provided useful information on the vadose zone media for the county. The ODNR, Division of Water, Glacial State Aquifer Map (2000) and Bedrock State Aquifer Map (2000) were important sources of vadose zone media data. The *Soil Survey of Putnam County* (Brock and Urban, 1974) provided valuable information on parent materials. The *Glacial Map of Ohio* (Goldthwait et al., 1961), and the *Quaternary Geology of Ohio* (Pavey et al., 1999) were useful in delineating vadose zone media.

The vadose zone media is a critical component of the overall DRASTIC rating in Putnam County. 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. The overall thickness of the glacial drift is also an important factor. In relatively thin drift (less than 25 feet), the till and lacustrine sediments are typically weathered and fractured, resulting in a higher vadose zone media rating. Where the drift is thicker, the majority of the sequence of till or lacustrine sediments typically is less weathered, less likely to be fractured, and is more compacted. These conditions would result in a more moderate to lower vadose zone media rating.

Limestone/fractured till with a vadose zone media rating of (6) was selected for parts of southeastern Putnam County where the till covering the underlying limestone was thin, averaging from roughly 8 to 24 feet. Vadose zone media of limestone with silt, clay, and fine sand was selected for limited areas in southern Putnam County and given a rating of (6). This vadose zone media was limited to the 7Ec-Alluvium over Sedimentary Rocks setting where the stream had eroded down close to the surface of the limestone, typically leaving less than fifteen feet of overlying alluvium. Glacial till was given vadose zone media rating of (5) and was used for an area of ground moraine in southeastern Riley Township. In this particular area, the till averaged over 25 feet thick and had no overlying lacustrine sediments.

A vadose zone media rating of (6) was chosen for sand and gravel with significant silt and clay for the majority of the areas with beach ridges and dunes throughout Putnam County. Vadose zone media ratings of (5) or (6) were selected for sand and gravel with significant silt and clay for some areas featuring coarse alluvium or terraces. Sand and gravel with significant silt and clay was given a vadose zone rating of (4) for the sandy, ablational area along the south side of the Defiance Moraine. In this area the sandy beach or ablational till overlies a thicker sequence of fine-grained till.

The *Soil Survey of Putnam County* (Brock and Urban, 1974) was used to help separate areas with silt and clay vadose zone media from areas of silt and clay with till vadose zone media depending upon whether lacustrine sediments or water-modified (wave-planed) till were the parent material for the soil. This distinction also was the primary criteria for separating the 7Fd-Wave-eroded Lake Plain from the 7F-Glacial Lake Deposits settings.

Silt and clay with ratings of (4) or (5) were selected for most alluvial settings in the county. The ratings varied according to the relative proportions of silt and clay comprising the alluvium and to how thick the underlying fine-grained till or lake deposits were. Silt and clay with a rating of (5) was commonly applied to stream or lake deposits with silt loam soils. These areas typically contained less than 50 feet of total drift and had a shallow to moderate depth to water. Silt and clay with a vadose zone media rating of (4) was applied to clayey alluvium and lake plain sediments that had weathered into shrink-swell (aggregated) clay soils. Silt and clay with a vadose zone media rating of (3) was utilized for areas with shrink swell clay soils derived from clayey lacustrine units that had a total thickness over 50 feet. These areas typically had a moderate to deep depth to water.

Silt and clay with till is comprised of exceptionally fine-grained till containing pockets of lacustrine silt and clay. Silt and clay with till with a vadose zone media rating of (6) or (5) was selected for limited areas in the 7Fd-Wave-eroded Lake Plain with clay loam or loam soils and moderate to shallow depths to water. Silt and clay with till with a vadose zone media rating of (4) was chosen for areas with a moderate thickness of till that had weathered to shrink-swell clay. Silt and clay with till with a vadose zone media rating of (3) was applied to limited areas of thick fine-grained till that was overlain by shrink-swell clay soils.

Hydraulic Conductivity

Information on evaluating the hydraulic conductivity was obtained from the maps and report of the ODNR, Div. of Water, (1970) and the *Ground Water Resources of Putnam County* (Calhoun, 1992). 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. Hydraulic conductivity ratings from the preliminary DRASTIC map for Putnam County thesis by Wurm (1992) were used as a guide. Ranges of values for hydraulic conductivity from neighboring Hancock County (Smith, 1994), Allen County (Angle and Barrett, 2005), Wood County (Smith and Sabol, 1994), and Henry County (Miller et al., 2002) served as a guideline. The thesis of Stuckey (1988) provided useful information on the hydraulic conductivity for the county. The ODNR, Division of Water, Glacial State Aquifer Map (2000) and Bedrock State Aquifer Map (2000) were important sources of hydraulic conductivity data. Additional site-specific hydraulic conductivity data included the report of Eagon & Associates (1997). Water well log records on file at the ODNR, Division of Water, were also used to help determine hydraulic conductivity. Textbook tables (Freeze and Cherry, 1979, Fetter, 1980, and Driscoll, 1986) were useful in obtaining estimated values for hydraulic conductivity in a variety of aquifers.

Values for hydraulic conductivity correspond to aquifer ratings; i.e., the more highly rated aquifers have higher values for hydraulic conductivity. Sand and gravel aquifers in the 7D1

Buried Valley setting have been assigned a hydraulic conductivity range of 700-1,000 gallons per day per square foot (gpd/ft^2) (6). This rating reflects the higher yields of the deeper sand and gravel layers in the core of the ancestral tributary to the Teays River Valley. All other sand and gravel aquifers in the remaining 7D-Buried Valley settings have been assigned a hydraulic conductivity range of 300-700 gpd/ft^2 (4) as the deposits tend to become finer-grained and thinner in the tributary headwaters of the Teays drainage system. All remaining sand and gravel aquifers outside of the 7D-Buried Valley setting were assigned a hydraulic conductivity range of 300-700 gpd/ft^2 (4). All limestone aquifers were assigned a hydraulic conductivity range of 300-700 gpd/ft^2 (4).

APPENDIX B

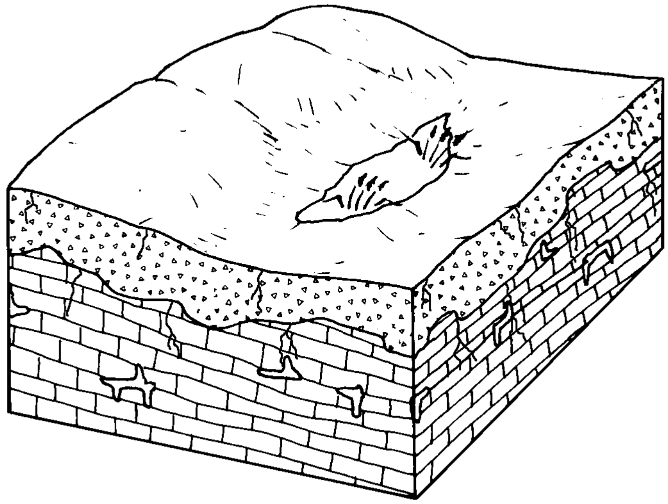
DESCRIPTION OF HYDROGEOLOGIC SETTINGS AND CHARTS

Ground water pollution potential mapping in Putnam County resulted in the identification of nine 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 Putnam County range from 95 to 159.

Table 12. Hydrogeologic settings mapped in Putnam County, Ohio

Hydrogeologic Settings	Range of GWPP Indexes	Number of Index Calculations
7 Ac-Glacial till over limestone	95-123	4
7 Af-Sand & gravel interbedded in glacial till	129	1
7 C-Moraine	95-123	9
7 D-Buried valley	136-158	5
7 Ec-Alluvium over sedimentary rock	135-150	10
7 F-Glacial Lake Plain Deposits	99-146	17
7 Fd-Wave-eroded lake plain	99-146	10
7 H-Beaches, beach ridges, and sand dunes	116-159	18

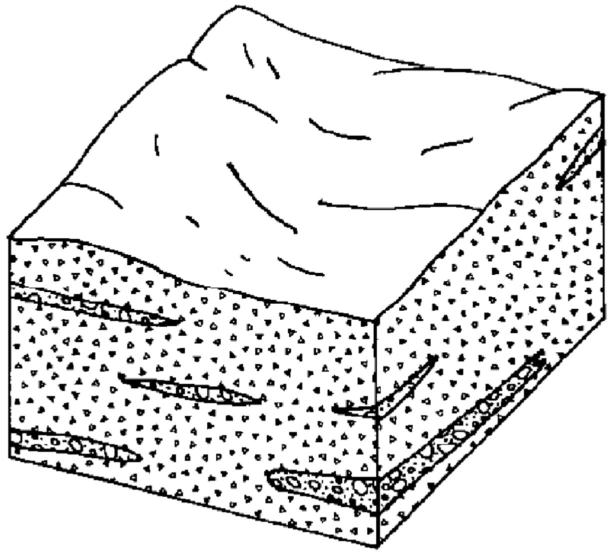
The following information provides a description of each hydrogeologic setting identified in the county, a block diagram illustrating the characteristics of the setting, and a listing of the charts for each unique combination of pollution potential indexes calculated for each setting. The charts provide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



7Ac-Glacial Till over Limestone

This hydrogeologic setting is limited to portions of southeastern Putnam County. These areas represent the only portions of the ground moraine that were at a high enough elevation not to be eroded by ancestral Lake Maumee. The area is characterized by flat-lying topography and low relief. The vadose zone consists primarily of silty to clayey glacial till. The till may be fractured or jointed, particularly in areas where it is predominantly thin and weathered. Where the till is very thin, fractured limestone is considered to be the vadose zone media together with the till. The aquifer is composed of fractured Silurian limestones and dolomites. These carbonate rocks may contain significant solution features. Depth to water is usually shallow, ranging from 15 to 30 feet. Soils typically are clay loams derived from till. Maximum ground water yields greater than 100 gpm are possible from the Silurian Lockport, Tymochtee, Greenfield and Salina Groups. Recharge is moderate due to the clayey nature of the soils and vadose zone and the relatively shallow depth to water and permeable nature of the bedrock aquifer. Recharge rates increase somewhat where the limestone bedrock is closer to the ground surface.

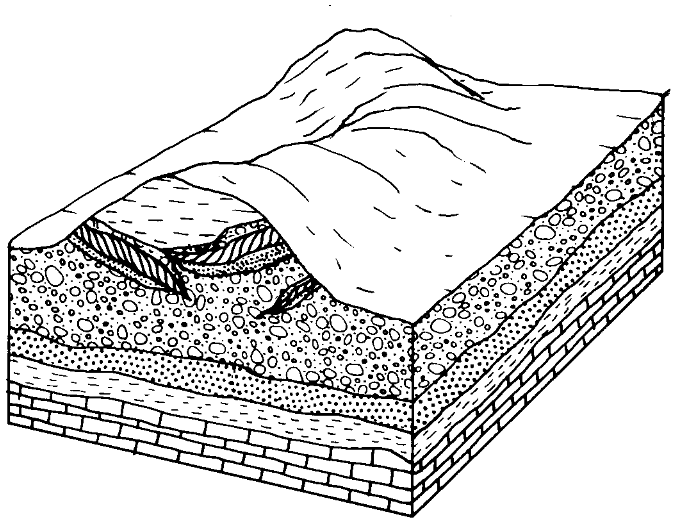
GWPP index values for the hydrogeologic setting of Glacial Till over Limestone range from 133 to 152, with the total number of GWPP index calculations equaling 4.



7Af-Sand & Gravel Interbedded in Glacial Till

This hydrogeologic setting is limited to a small area in southeastern Putnam County. The area is characterized by flat lying topography and low relief. The setting is commonly associated with areas of ground moraine. This setting is similar to the 7Ac-Glacial Till over Limestone setting except that the drift is thicker and contains small sand and gravel lenses that serve as the aquifer. 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 relatively shallow. Soils are clay loams. The aquifer consists of thin lenses of sand and gravel interbedded in the glacial till. Ground water yields range from 5 to 25 gpm. Recharge is moderate due to the relatively low permeability of the clayey soils and vadose zone material and the relative shallow depth to the sand and gravel aquifers.

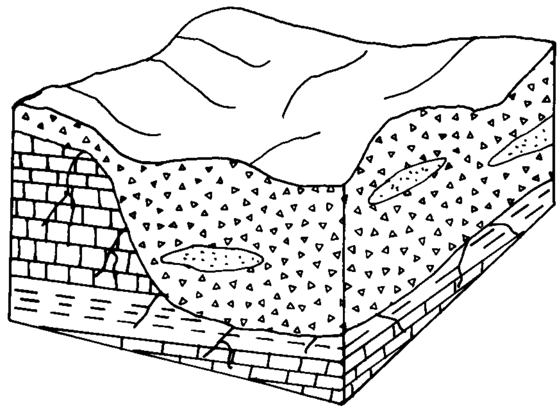
The GWPP index value for the hydrogeologic setting of Sand & Gravel Interbedded in Glacial Till is 129, with the total number of GWPP index calculations equaling 1.



7C-Moraine

This hydrogeologic setting consists of a broad subdued ridge lying just south of Leipsic in northeastern Putnam County. This setting is characterized by gentle hummocky to rolling topography that stands out from the surrounding flat lake plain. The setting represents where the Defiance End Moraine was surrounded and probably washed over by ancestral Lake Maumee. The aquifer is typically Silurian limestone or dolomite bedrock. In limited areas, the aquifer consists of sand and gravel lenses interbedded with the fine-grained glacial till. Yields for the sand and gravel lenses average from 5 to 25 gpm. Maximum ground water yields greater than 100 gpm are possible from the Silurian Lockport, Tymochtee, Greenfield and Salina Groups. The vadose zone is composed of silty to clayey glacial till or lacustrine sediments. The till may be fractured or jointed, particularly in areas where it is predominantly thin and weathered. On the south side of the moraine is an area of sandier soils. This may represent shoreline erosion/deposition or perhaps ablation till. Depth to water is moderate to deep and depends primarily upon how deep the underlying aquifer is. Depths to water increase along the central axis or ridge of the end moraines. Soils are clay loam to shrink-swell clay on the north side of the moraine. Soils are loams on the sandier southern side of the moraine. Recharge is moderate to low depending upon how thick the till is and how deep the underlying aquifer is.

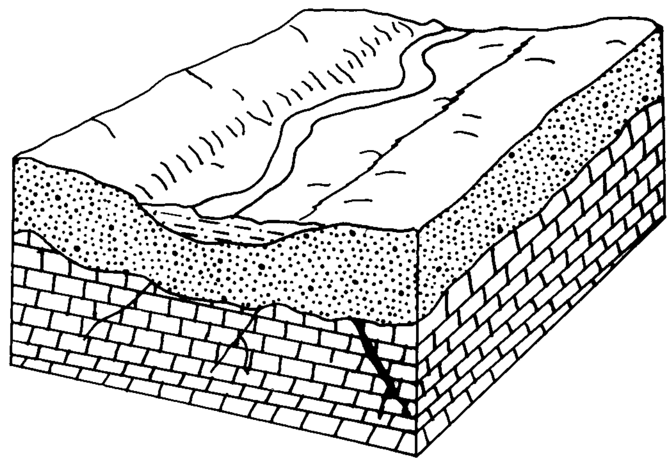
GWPP index values for the hydrogeologic setting of Moraine range from 95 to 123, with the total number of GWPP index calculations equaling 9.



7D-Buried Valley

This hydrogeologic setting consists of a narrow, north-south running band that extends from the border of Allen County into southwestern Putnam County. The axis of this buried valley marks the ancestral channel of a major tributary of the Teays River System. The surface topography is flat and has low relief. Modern streams typically do not overly these deposits. The setting is characterized by a thick sequence of glacial till, covered by a varying thickness of fine-grained lacustrine sediments in some areas. The aquifer consists of thinner, less continuous lenses of sand and gravel interbedded with thicker sequences of fine-grained glacial till. At greater depths, the layers of sand and gravel become thicker, cleaner, and more productive. Thin layers of alluvial or lacustrine silt, clay, or fine sand may also be present at greater depths. Yields from the sand and gravel lenses are commonly less than 25 gpm. Test drilling may encounter thicker sand and gravel lenses that may produce over 100 gpm from large diameter wells. Soils are usually clay loams or shrink-swell clays derived from the overlying glacial till or lacustrine sediments. Depths to water are relatively shallow. Recharge is typically moderate due to the fine-grained nature of the soils and vadose zone media, and the relatively shallow depth to the sand and gravel aquifers.

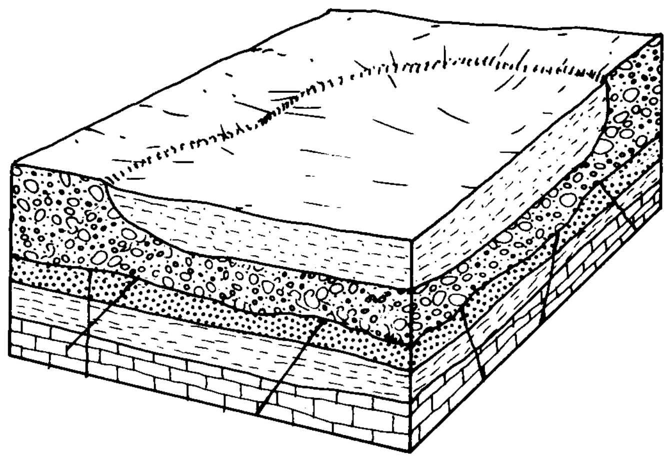
GWPP index values for the hydrogeologic setting of Buried Valley range from 136-158, with the total number of GWPP index calculations equaling 5.



7Ec-Alluvium over Sedimentary Rock

This hydrogeologic setting is common throughout Putnam County, and is comprised of flat-lying floodplains and stream terraces containing thin to moderate thicknesses of modern alluvium. The aquifers consist of Silurian limestones and dolomites. The vadose zone consists of the sandy to silty to clayey alluvial deposits overlying thin glacial till. In some places, the limestone bedrock is close enough to the surface to comprise part of the vadose zone media. Soils are variable due to the varying texture of the alluvial materials. Depth to water is commonly very shallow, averaging less than 20 feet. The alluvium may be in direct hydraulic connection with the underlying bedrock or there may be thin till or lacustrine deposits in between. Maximum ground water yields greater than 100 gpm are possible from the Silurian Lockport, Tymochtee, Greenfield and Salina Groups. Recharge is typically moderately high due to the flat-lying topography, shallow depth to water, the moderate permeability of the soils and vadose zone media, and the relatively high permeability of the underlying bedrock.

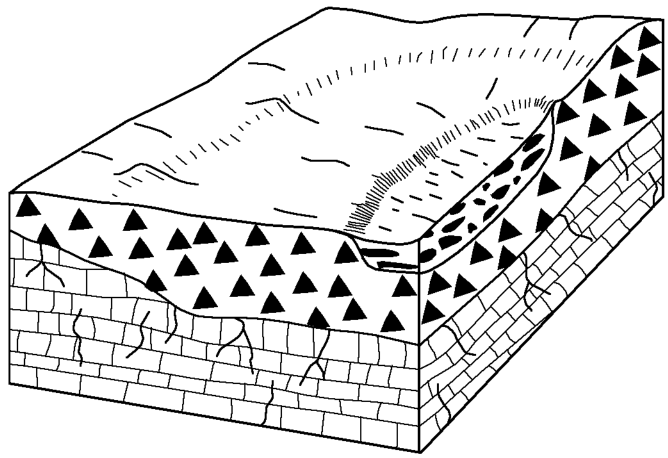
The GWPP index values for the hydrogeologic setting Alluvium over Sedimentary Rocks range from 135 to 150, with the total number of GWPP index calculations equaling 10.



7F Glacial Lake Plain Deposits

This hydrogeologic setting occupies a broad area in central, western, and northwestern Putnam County. This hydrogeologic setting is characterized by flat-lying topography and varying thickness of fine-grained lacustrine sediments. These sediments were deposited in lakes and deltas by a sequence of ancestral lakes. The vadose zone media consists of silty to clayey lacustrine sediments or silty deltaic sediments that overlie glacial till. In limited areas the aquifer consists of thin sand and gravel lenses interbedded in the underlying till and lacustrine sediments. Yields for these sand and gravel wells range from 5 to 25 gpm. Most wells are completed in the underlying Silurian and Devonian limestone and dolomite. Maximum ground water yields greater than 100 gpm are possible from the Silurian Lockport, Tymochtee, Greenfield and Salina Groups. Depth to water is shallow to moderate, averaging less than 50 feet. Soils vary with the surficial deposits and are shrink-swell (aggregated) clays or clay loams derived from clayey lacustrine sediments and silt loams derived from deltaic sediments. The presence of shrink-swell clay soils is important due to the fact that desiccation cracks in these soils form during prolonged dry spells. These cracks serve as conduits for contaminants to move through these normally low permeability soils. The vadose zone is comprised of fine-grained lacustrine sediments overlying till in some areas. Recharge in this setting is moderate to low depending upon the depth to water and the thickness of the fine-grained lacustrine sediments and till.

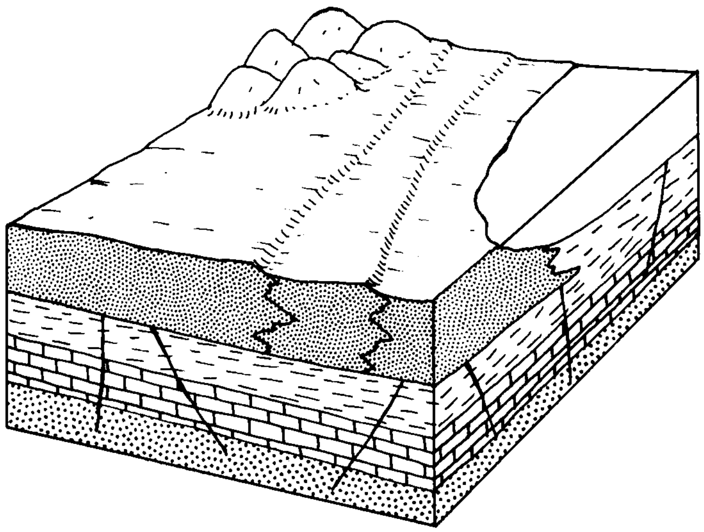
GWPP index values for the hydrogeologic setting of Glacial Lake Plains Deposits range from 99 to 146 with the total number of GWPP index calculations equaling 17.



7Fd-Wave-eroded Lake Plain

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

GWPP index values for the hydrogeologic setting of Wave-eroded Lake Plain range from 99 to 146, with the total number of GWPP index calculations equaling 10.



7H-Beaches,Beach Ridges, 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 most prevalent in eastern Putnam County. The vadose zone media is composed of thin, clean, fine-grained quartz sand that has moderately high permeability and low sorptive capability. These thin sands overlie lower permeability clayey lacustrine deposits and water-modified till. Wells are completed in Silurian limestone and dolomite bedrock that underlies the till and lacustrine sediments. Maximum ground water yields greater than 100 gpm are possible from the Silurian Lockport, Tymochtee, Greenfield and Salina Groups. Depth to water is typically fairly shallow. Soils are loams or sandy loams depending upon how fine-grained the beach deposits are. Recharge is moderately high due to shallow depth to water and highly permeable soils and vadose material.

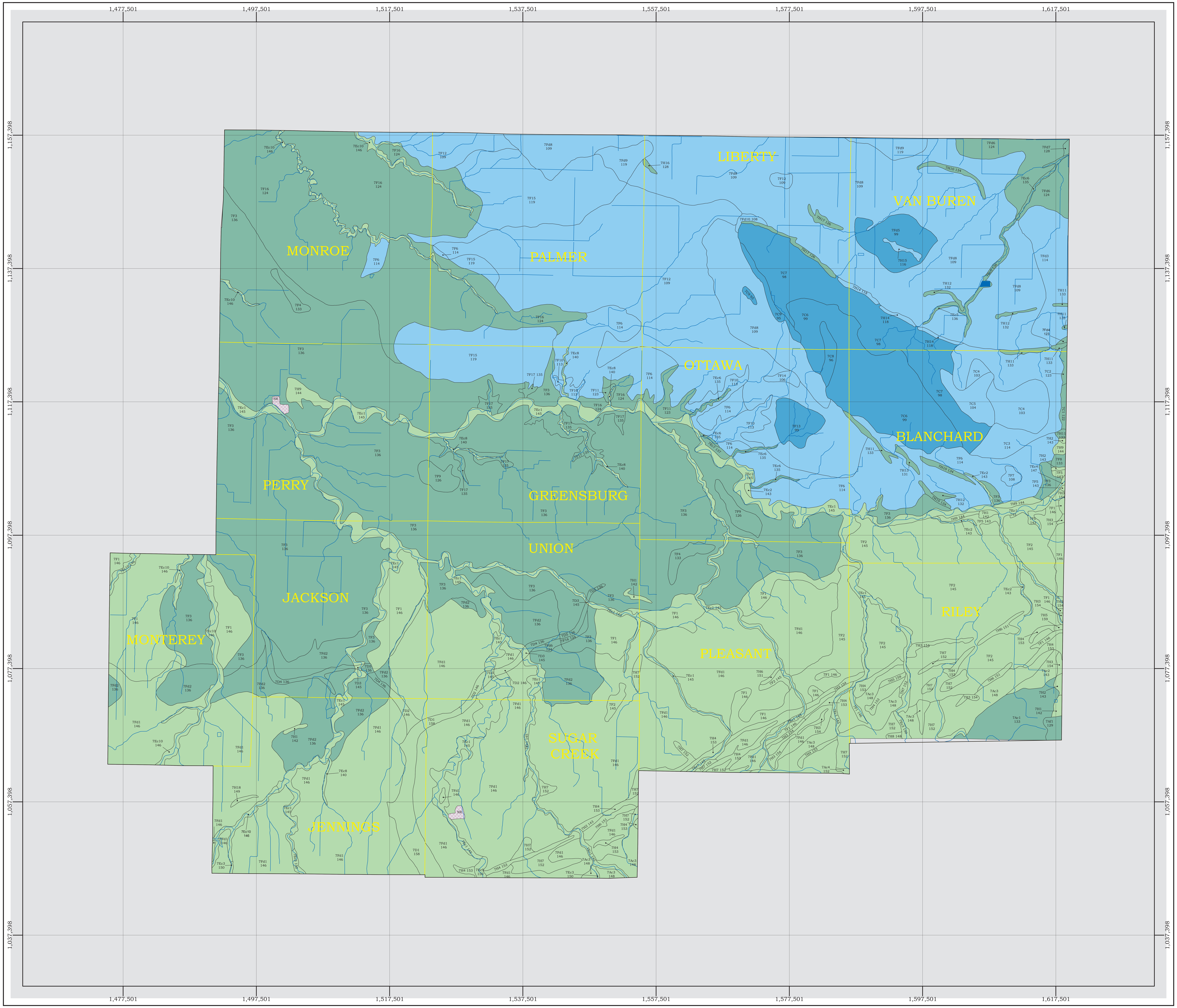
GWPP index values for the hydrogeologic setting of Beaches, Beach Ridges, and Sand Dunes range from 116 to 159, with the total number of GWPP index calculations equaling 18.

Table 13. Hydrogeologic Settings, DRASTIC Factors, and Ratings

Setting	Depth to Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% slope)	Vadose Zone Media	Hydraulic Conductivity	Rating	Pesticide Rating
7Ac1	15-30	4-7	limestone	Clay Loam	0-2	till	300-700	133	153
7Ac2	5-15	4-7	limestone	Clay Loam	0-2	till	300-700	143	163
7Ac3	5-15	4-7	limestone	Clay Loam	0-2	lst-frac till	300-700	148	167
7Ac4	5-15	4-7	limestone	Loam	0-2	lst-frac till	300-700	152	177
7Af1	15-30	4-7	sand & gravel	Clay Loam	2-6	sd + gvl w/sl + cl	300-700	129	147
7C1	30-50	4-7	limestone	Clay Loam	2-6	sl + cl w/till	300-700	122	140
7C2	30-50	4-7	limestone	Clay Loam	0-2	sl + cl w/till	300-700	123	143
7C3	30-50	2-4	limestone	Shrink/Swell Clay	0-2	sl + cl w/till	300-700	114	147
7C4	50-75	2-4	limestone	Shrink/Swell Clay	2-6	sl + cl w/till	300-700	103	134
7C5	50-75	2-4	limestone	Shrink/Swell Clay	0-2	sl + cl w/till	300-700	104	137
7C6	50-75	2-4	limestone	Loam	2-6	sd + gvl w/sl + cl	300-700	99	124
7C7	50-75	2-4	limestone	Shrink/Swell Clay	2-6	sl + cl w/till	300-700	98	130
7C8	50-75	2-4	sand & gravel	Loam	2-6	sd + gvl w/sl + cl	300-700	96	121
7C9	50-75	2-4	limestone	Clay Loam	2-6	sl + cl w/till	300-700	95	114
7D1	5-15	4-7	sand & gravel	Loam	0-2	sl + cl w/till	700-1000	158	181
7D2	5-15	4-7	sand & gravel	Shrink/Swell Clay	0-2	sl + cl w/till	300-700	146	179
7D3	5-15	4-7	sand & gravel	Silty Loam	0-2	silt and clay	300-700	145	168
7D4	15-30	4-7	sand & gravel	Shrink/Swell Clay	0-2	sl + cl w/till	300-700	136	169
7D5	15-30	4-7	sand & gravel	Shrink/Swell Clay	0-2	silt and clay	300-700	136	169
7Ec1	5-15	4-7	limestone	Silty Loam	0-2	silt and clay	300-700	145	168
7Ec2	5-15	4-7	limestone	Clay Loam	0-2	silt and clay	300-700	143	163
7Ec3	5-15	4-7	limestone	Silty Loam	0-2	ls/sl-cl-sd	300-700	150	172
7Ec4	5-15	4-7	limestone	Loam	0-2	sd + gvl w/sl + cl	300-700	147	173
7Ec5	15-30	4-7	limestone	Shrink/Swell Clay	0-2	silt and clay	300-700	136	169

Setting	Depth to Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% slope)	Vadose Zone Media	Hydraulic Conductivity	Rating	Pesticide Rating
7Ec6	15-30	4-7	limestone	Silty Loam	0-2	silt and clay	300-700	135	158
7Ec7	15-30	4-7	limestone	Loam	0-2	sd + gvl w/sl + cl	300-700	137	163
7Ec8	5-15	4-7	limestone	Silty Loam	0-2	silt and clay	300-700	140	164
7Ec9	5-15	4-7	limestone	Silty Loam	0-2	sd + gvl w/sl + cl	300-700	150	172
7Ec10	5-15	4-7	limestone	Shrink/Swell Clay	0-2	silt and clay	300-700	146	179
7F1	5-15	4-7	limestone	Shrink/Swell Clay	0-2	silt and clay	300-700	146	179
7F2	5-15	4-7	limestone	Silty Loam	0-2	silt and clay	300-700	145	168
7F3	15-30	4-7	limestone	Shrink/Swell Clay	0-2	silt and clay	300-700	136	169
7F4	15-30	4-7	sand & gravel	Shrink/Swell Clay	0-2	silt and clay	300-700	133	166
7F5	5-15	4-7	limestone	Clay Loam	0-2	sl + cl w/till	300-700	143	163
7F6	30-50	2-4	limestone	Shrink/Swell Clay	0-2	silt and clay	300-700	114	147
7F7	30-50	2-4	limestone	Silty Loam	0-2	silt and clay	300-700	108	132
7F8	15-30	4-7	limestone	Clay Loam	0-2	sl + cl w/till	300-700	133	153
7F9	30-50	4-7	limestone	Shrink/Swell Clay	0-2	silt and clay	300-700	126	159
7F10	30-50	2-4	limestone	Shrink/Swell Clay	2-6	silt and clay	300-700	113	144
7F11	15-30	2-4	limestone	Shrink/Swell Clay	2-6	silt and clay	300-700	123	154
7F12	30-50	2-4	limestone	Shrink/Swell Clay	0-2	silt and clay	300-700	109	143
7F13	50-75	2-4	limestone	Shrink/Swell Clay	0-2	silt and clay	300-700	99	133
7F14	30-50	2-4	sand & gravel	Shrink/Swell Clay	0-2	silt and clay	300-700	106	140
7F15	15-30	2-4	limestone	Shrink/Swell Clay	0-2	silt and clay	300-700	119	153
7F16	15-30	2-4	limestone	Shrink/Swell Clay	0-2	silt and clay	300-700	124	157
7F17	15-30	4-7	limestone	Shrink/Swell Clay	2-6	silt and clay	300-700	135	166
7Fd1	5-15	4-7	limestone	Shrink/Swell Clay	0-2	sl + cl w/till	300-700	146	179
7Fd2	15-30	4-7	limestone	Shrink/Swell Clay	0-2	sl + cl w/till	300-700	136	169
7Fd3	30-50	2-4	limestone	Shrink/Swell Clay	0-2	sl + cl w/till	300-700	114	147
7Fd4	30-50	4-7	limestone	Clay Loam	0-2	sl + cl w/till	300-700	123	143

Setting	Depth to Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% slope)	Vadose Zone Media	Hydraulic Conductivity	Rating	Pesticide Rating
7Fd5	50-75	2-4	limestone	Shrink/Swell Clay	0-2	sl + cl w/till	300-700	99	133
7Fd6	15-30	2-4	limestone	Shrink/Swell Clay	0-2	sl + cl w/till	300-700	124	157
7Fd7	15-30	4-7	limestone	Clay Loam	0-2	sl + cl w/till	300-700	128	149
7Fd8	30-50	2-4	limestone	Shrink/Swell Clay	0-2	sl + cl w/till	300-700	109	143
7Fd9	15-30	2-4	limestone	Shrink/Swell Clay	0-2	sl + cl w/till	300-700	119	153
7Fd10	30-50	2-4	limestone	Shrink/Swell Clay	2-6	sl + cl w/till	300-700	108	140
7H1	15-30	4-7	limestone	Loam	0-2	sd + gvl w/sl + cl	300-700	142	167
7H2	15-30	4-7	limestone	Sandy Loam	2-6	sd + gvl w/sl + cl	300-700	143	169
7H3	5-15	4-7	limestone	Sandy Loam	0-2	sd + gvl w/sl + cl	300-700	154	182
7H4	5-15	4-7	limestone	Sandy Loam	2-6	sd + gvl w/sl + cl	300-700	153	179
7H5	5-15	4-7	limestone	Sand	2-6	sd + gvl w/sl + cl	300-700	159	194
7H6	5-15	4-7	limestone	Loam	2-6	sd + gvl w/sl + cl	300-700	151	174
7H7	5-15	4-7	limestone	Loam	0-2	sd + gvl w/sl + cl	300-700	152	177
7H8	5-15	4-7	limestone	Clay Loam	0-2	sd + gvl w/sl + cl	300-700	148	167
7H9	15-30	4-7	limestone	Sandy Loam	0-2	sd + gvl w/sl + cl	300-700	144	172
7H10	30-50	4-7	limestone	Sandy Loam	0-2	sd + gvl w/sl + cl	300-700	134	162
7H11	30-50	4-7	limestone	Sandy Loam	2-6	sd + gvl w/sl + cl	300-700	133	159
7H12	30-50	4-7	limestone	Loam	0-2	sd + gvl w/sl + cl	300-700	132	157
7H13	30-50	4-7	limestone	Loam	2-6	sd + gvl w/sl + cl	300-700	131	154
7H14	50-75	4-7	limestone	Sandy Loam	2-6	sd + gvl w/sl + cl	300-700	118	145
7H15	50-75	4-7	limestone	Loam	2-6	sd + gvl w/sl + cl	300-700	116	140
7H16	30-50	4-7	limestone	Sandy Loam	2-6	sd + gvl w/sl + cl	300-700	128	155
7H17	30-50	4-7	limestone	Loam	2-6	sd + gvl w/sl + cl	300-700	126	150
7H18	5-15	4-7	limestone	Sandy Loam	0-2	sd + gvl w/sl + cl	300-700	149	178



Ground Water Pollution Potential of Putnam County

by

Mike Angle

Ohio Department of Natural Resources

Division of Water

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

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

Description of Map Symbols

Hydrogeologic Region → 7D24 ← Hydrogeologic Setting

170 ← Relative Pollution Potential

Legend

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

- Roads
- Streams
- Lakes
- Townships

Index Ranges

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

N

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

0 1 2 3 4 5
Miles

0 1 2 4 6 8
Kilometers

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