GROUND WATER POLLUTION POTENTIAL
OF MARION COUNTY, OHIO

BY

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ABSTRACT

A ground water pollution potential map of Marion 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 Marion County resulted in a map with symbols and colors, which illustrate areas of varying ground water pollution potential indexes ranging from 105 to 167.

Marion County lies entirely within the Glaciated Central hydrogeologic setting. Limestones and dolomites of the Silurian and Devonian Systems compose the aquifer in the western and central portions of the county. Yields in the uppermost carbonate aquifers range from 5 to 100 gallons per minute (gpm). Yields over 100 gpm are possible from larger diameter wells drilled deeper into the limestone. Shales of the Devonian System and Mississippian System comprise the aquifer in the eastern quarter 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 portions of eastern Marion County. Sand and gravel lenses are most predominant in areas with shale bedrock. In some areas, the sand and gravel lenses may lie directly on top of the shale 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.

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 Marion 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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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; 7200 of these wells exist in Marion 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 Marion 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 Marion 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

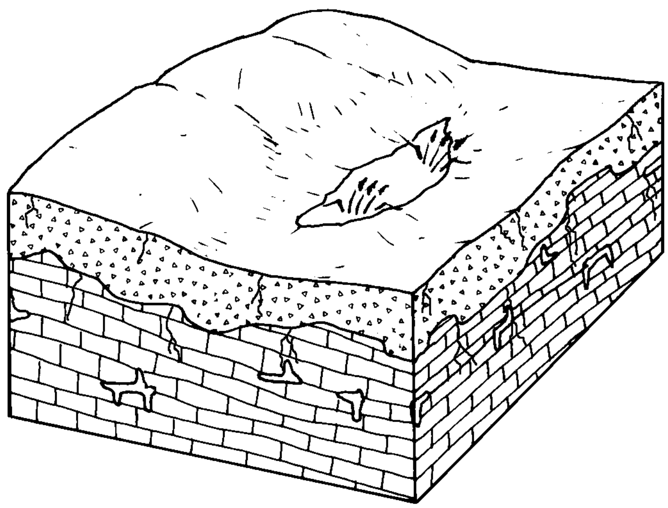
These factors incorporate concepts and mechanisms such as attenuation, retardation, and time or distance of travel of a contaminant with respect to the physical characteristics of the hydrogeologic setting. Broad consideration of these factors and mechanisms coupled with existing conditions in a setting 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 widespread in western and central Marion County. The area is characterized by flat-lying topography and very low relief associated with ground moraine. 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 the vadose zone media. The aquifer is composed of fractured Silurian and/or Devonian limestones and dolomites. These carbonate rocks may contain significant solution features. Depth to water is typically shallow to moderate, ranging from 15 to 50 feet. Soils are variable but 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. Yields range from 5 to 100 gpm for the Devonian carbonate units. Recharge is moderate to low due to the clayey nature of the soils and vadose zone and the relatively shallow depth to water.

GWPP index values for the hydrogeologic setting of Glacial Till over Solution Limestone range from 106 to 159, with the total number of GWPP index calculations equaling 20.

Figure 1. Format and description of the hydrogeologic setting – 7Ac 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 and 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 and Gravel with Silt and Clay	4-8	6
Glacial Till	2-6	4
Sand and Gravel	6-9	8
Karst Limestone	8-10	10
Weight: 5	Pesticide Weight: 4	

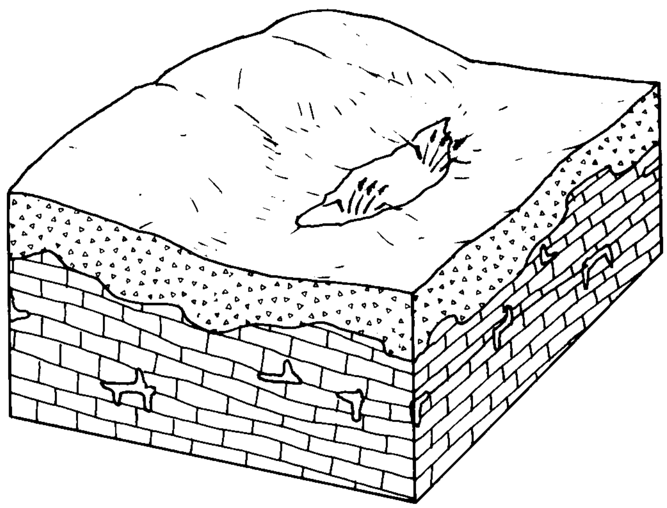
Table 8. Ranges and ratings for hydraulic conductivity

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, Till over Limestone, identified in mapping Marion 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 143. 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 Marion 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 105 to 167.

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 Marion 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 Marion County is included with this report.



SETTING 7Ac1		GENERAL		
FEATURE	**RANGE**	**WEIGHT**	**RATING**	**NUMBER**
Depth to Water	5-15	5	9	45
Net Recharge	4-7	4	6	24
Aquifer Media	Limestone	3	7	21
Soil Media	Clay Loam	2	3	6
Topography	0-2%	5	10	10
Impact of Vadose Zone	Till	5	5	25
Hydraulic Conductivity	300-700	3	4	12
		DRASTIC	INDEX	143

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

INTERPRETATION AND USE OF GROUND WATER POLLUTION POTENTIAL MAPS

The application of the DRASTIC system to evaluate an area'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
143 - defines the relative pollution potential

Here 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 (**143**) 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 MARION COUNTY

Demographics

Marion County occupies approximately 404 square miles in north central Ohio (Figure 3). Marion County is bounded to the north by Wyandot County and Crawford County, to the east by Morrow County, to the south by Delaware County, to the southwest by Union County, and to the west by Hardin County.

The approximate population of Marion County, based upon year 2000 census estimates, is 66,217 (Department of Development, Ohio County Profiles, 2003). The City of Marion is the largest community and the county seat. Agriculture accounts for roughly 86 percent of the land usage in Marion 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 51 degrees Fahrenheit for Marion County. The average temperatures decrease slightly towards the northeast. Harstine (1991) shows that precipitation approximately averages 36 inches per year for the county, with precipitation decreasing towards the west. The mean annual precipitation for Marion (City) is 38.35 inches per year based upon a thirty-year (1971-2000) period (National Oceanographic and Atmospheric Administration (NOAA), 2002). The mean annual temperature at Marion (City) for the same thirty-year period is 49.6 degrees Fahrenheit ((National Oceanographic and Atmospheric Administration (NOAA), 2002).

Physiography and Topography

Marion County lies within the Central Till Plains Lowland Province (Frost, 1931; Fenneman, 1938, and Bier, 1956). Brockman (1998) and Schiefer (2002) depict Marion County as belonging in the Central Ohio Clayey Till Plain. Marion County is characterized by flat ground moraine and intermorainal lakes separated by linear, hummocky end moraines.

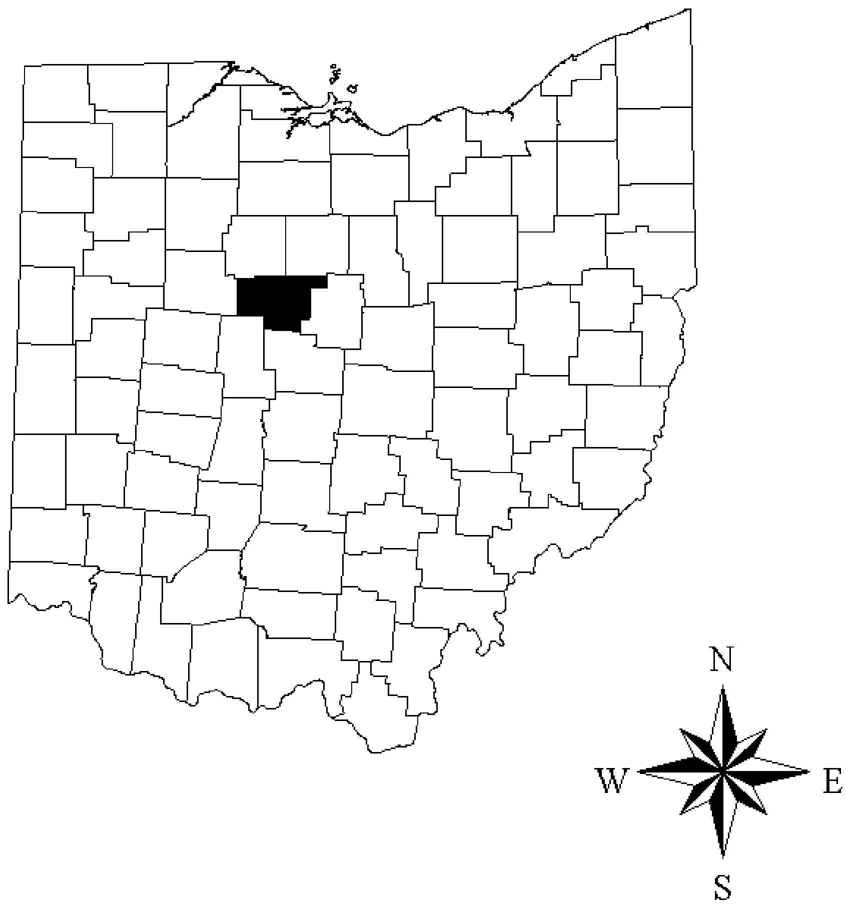


Figure 3. Location map of Marion County, Ohio.

Modern Drainage

The divide between the headwaters of the Lake Erie Basin and the Ohio River Basin extends across northwestern Marion County. The headwaters of both Tymochtee Creek and the Little Sandusky River drain the northwestern corner of the county; and drain toward the Lake Erie Basin. The remainder of the county drains southward, ultimately to the Scioto River and the Ohio River. The Olentangy River drains eastern Marion County. The Little Scioto River drains the north central portion of the county. The Scioto River drains the southwestern and south central portions of the county. The Scioto River flows roughly eastward past Larue and then turns sharply southward near Green Camp.

Pre- and Inter-Glacial Drainage Changes

Little information is available on the pre-glacial drainage of Marion County (Totten, 1986). Marion County lacks the deep buried valley systems that are crucial in determining the pre-glacial drainage history (Totten, 1986). Stout et al. (1943) suggested that during pre-glacial (Teays Stage Drainage) times that northern Marion County contained the headwaters of the Tiffin River. The Tiffin River was an ancestor of, and had a course similar to, that of the modern Sandusky River. The southern portion of Marion County presumably drained to the south or southwest by tributaries of the Teays River System (Stout et al., 1943). Following the onset of glaciation, an ancestral Scioto River drained the southern portion of the county. The drainage patterns of Marion County largely reflect the terrain resulting from the final Wisconsinan glacial advances.

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), Totten (1986), and Pavey et al., (1999) report that the last advance, the Late Wisconsinan Ice Sheet, deposited the surficial till in Marion County. Evidence for the earlier glaciations is lacking or obscured.

Totten (1986) discussed the glacial deposits of Marion County at length. In a recent study, Russell (2002) reevaluated the lacustrine deposits related to the intermorainal lakes found in neighboring Crawford County. His study was the basis for the delineation of the 7Fc-Intermorainal Lake Deposits hydrogeologic setting. These deposits extend into Marion County. The *Soil Survey of Marion County* (Miller and Martin, 1989) was used to make the delineations between the lakebeds and ground moraine. The exceptional flatness of these features and characteristics of poor drainage also proved useful in delineating the intermorainal lakes. The majority of the glacial deposits in Marion County fall into four main types: (glacial) till, lacustrine deposits, outwash (valley train) deposits, and ice-contact sand and gravel (kames, eskers) deposits. 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 somewhat in end moraines. There are many isolated areas in Marion County where the drift is very thin and the bedrock is very close to the ground surface (Totten, 1986, 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-rich environment in Marion 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.

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). Of importance in the end moraines of Marion County is the high proportion of sand and gravel units interbedded in the till. These units may overlap enough (“stack”) to help aid in permeability. Fractures may also interconnect the 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. 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. The St. Johns Moraine roughly parallels the southern margin of the Scioto River through Bowling Green Township and Green Camp Township and then trends northeastward towards the city of Marion. A segment or portion of the St. Johns Moraine is also evident in Scott Township. The Wabash Moraine roughly follows the northern margin of the Scioto River in Montgomery Township and Big Island Township and the western margin of the Little Scioto River in Marion Township and Grand Prairie Township.

Outwash deposits are created by active deposition of sediments by meltwater streams. These deposits are generally bedded or stratified and are sorted. Outwash deposits in Marion County are mostly associated with the Scioto River near La Rue and also between Green Camp and Prospect. Outwash deposits associated with stream valleys were referred to in earlier literature as valley trains. Sorting and degree of coarseness depend upon the nature and proximity of the melting ice sheet. Braided streams usually deposited the outwash. Such streams have multiple channels, which migrate across the width of the valley floor, leaving behind a complex record of deposition and erosion. Deposition of outwash may precede an advancing ice sheet or be associated with a melting ice sheet. As modern streams downcut, the older, now higher elevation, remnants of the original valley floor are called terraces. The outwash deposits in Marion County tend to have a significant proportion of relatively fine-grained sand and silt layers. The outwash deposits flanking the Scioto River are definitely finer-grained than those found further south in Franklin County. This would seem to indicate that the sediments were deposited by relatively slow-moving meltwater. It is likely that the flow was partially restricted or blocked, perhaps by ice or while the ancestral Scioto River was cutting through a moraine further downstream (Totten, 1986).

Kames and eskers are ice contact features. They are composed of masses of generally poorly sorted sand and gravel with minor till, deposited in depressions, holes, tunnels, or other cavities in the ice. As the surrounding ice melts, a mound of sediment remains behind. Typically, these deposits may collapse or flow as the surrounding ice melts. These deposits may display high angle, distorted or tilted beds, faults, and folds. Kames are comprised of isolated or small groups of rounded mounds of dirty sand and gravel with minor till. Eskers are comprised of elongate, narrow, sinuous ridges of sand and gravel. Kame terraces are a linear belt of kames that have a similar appearance and a fairly uniform elevation. Kame terraces commonly flank valleys or streams. The best examples of ice contact deposits are kames found along the Scioto River between Prospect and Green Camp and kame terraces flanking Ququa Creek northwest of Waldo (Totten, 1986). Small remnants of an esker in the Prospect area are probably associated with a prominent esker found in Radnor in adjacent Delaware County. The Radnor Esker is one of the more prominent eskers in central Ohio.

Marion County contains abundant kettles. Kettles are usually associated with areas of ablation where the ice sheet was actively melting. Melting blocks of ice formed these small, circular depressional features. As the ice block melted, it left behind a hole or low area surrounded by either till or outwash. Kettles may also reflect lows or "swales" in an end moraine which are flanked by highs or "swells". Kettles commonly contain standing water. The water may reflect the local water table conditions or may collect and perch local runoff. Kettles also contain peat and muck. Peat and muck are organic-rich deposits associated with low-lying depression areas, bogs, kettles, and swamps. Muck is dense, fine silt with a high content of organics and a dark black color. Peat is typically brownish and contains pieces of plant fibers, decaying wood, and mosses. The two deposits commonly occur together; the *Soil Survey of Marion County* (Miller and Martin, 1989) shows organic deposits that have filled kettles. The kettles are typically underlain by either highly permeable sand and gravel outwash or by low permeability lacustrine silt and clay or till. Kettles are found in the lakebed deposits associated with former Lake Marseilles in Grand Township and found in the hummocky terrain flanking the St. Johns Moraine in Scott Township.

Lacustrine deposits are composed of silty to clayey material. These lakes are referred to as intermorainal lakes as they occupy low areas of ground moraine between end moraines. The lakes tend to become somewhat finer-grained near the center of the deposit or lake (Gregory, 1956, House, 1985, Totten, 1986, and Russell, 2002). Lacustrine deposits tend to be laminated (or varved) and contain various proportions of silts and clays. Thin layers of fine sand interbedded with the clayey to silty lacustrine deposits 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. Thin layers of sand typically occupy the margins of the lakes. These sands may reflect minor deltas that started to prograde into the lake, or they may mark the rough beginnings of a beach along the shoreline.

The lakes were created during the recession of the ice sheets. Meltwater was trapped between the receding ice sheet and end moraines. In some areas, meltwater may have been trapped between two end moraines forming a lake. Additional ponding may have resulted from northerly-flowing, run-off fed streams that were blocked by the ice sheets. Run-off in general helped to fill these ponds. Eventually, some of these ponds may have overflowed their margins and began to cut an outlet. House (1985) and Russell (2002) theorized that as one lake overflowed, it would progressively cause the next lower elevation lake to overflow. Alternatively, the headwaters of emerging streams may have cutback and created an outlet for the lakes. As the modern drainage system slowly developed, streams downcut through the series of end moraines, draining the lakes over time. Swampy bog and kettle areas replaced many of the lakes. Many of these features persist today or were recently drained for agriculture.

Glacial Lake Marseilles occupies the low area between the Wabash Moraine and the Fort Wayne Moraine in southern Wyandot County. This former lakebed covers most of Grand Township and Salt Rock Township. Glacial Lake Marion occupies the low area between the Wabash Moraine and the St. Johns Moraine. The Scioto River cuts through the former lakebed. A third major lakebed, informally named Lake Dallas (Russell, 2002), extends south from Crawford County (Russell, 2002) and lies in a low area between the St. Johns Moraine and the Olentangy River in eastern Scott Township.

Bedrock Geology

Bedrock underlying the surface of Marion County belongs to the Silurian, Devonian, and Mississippian Systems. Carbonate (limestone and dolomite) bedrock underlies the western and central portions of Marion County; the eastern portion is underlain by shale. Table 9 summarizes the bedrock stratigraphy found in Marion County. The ODNR, Division of Geological Survey has Open-File Reconnaissance Bedrock Geological 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.

Silurian and Devonian carbonates are found in the western and central portions of Marion County. The oldest unit typically encountered by water wells is the Silurian Lockport Group. The Lockport Group rocks were associated with tidal reefs deposited in warm, high-energy shallow seas. Rocks of the Lockport are the uppermost bedrock unit in the northwestern corner of Marion County and become progressively deeper buried to the east. Overlying the Lockport Group are rocks of the Silurian Tymochtee and Greenfield Formations, which were

Table 9. Bedrock stratigraphy of Marion County

System	Group/Formation (Symbol)	Lithologic Description
Mississippian	Bedford Shale (Mbd)	Gray to brown, soft, massive, fine-grained, clay-rich shale. Local thickness <100 feet. Very poor aquifer, typically yielding <5 gpm.
Devonian	Ohio and Olentangy Shales (Dohol)	Black to brownish-black, thin-bedded, organic, pyritic, carbonaceous shale. Thickness >100 feet in eastern part of the county, and thins westward. Poor aquifer, typically yielding <5 gpm.
	Delaware and Columbus Limestones (Ddc)	The Delaware is a gray to brown thin-bedded to massive, argillaceous, carbonaceous limestone. The Columbus is a gray to brown, fossiliferous, massive-bedded limestone and dolomite. Karst features are common in the Columbus. In much of Marion County, these units are >100 feet in thickness. Yields are usually 5-100 gpm. Thickness and yields for these formations decreases toward the western edge of the county. The water quality deteriorates in areas where these units are overlain by thick Ohio and Olentangy Shale.
Silurian	Undifferentiated Salina Dolomite (Sus)	Gray to brown, thin-bedded, argillaceous dolomite. Thin evaporite zones common. Thickness >100 feet. Yields may exceed 100 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 litho logy. Combined thickness exceeds 100 feet. Yields can be >100 gpm, especially in the Tymochtee.
	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.

also deposited in warm, shallow seas. These two formations tend to become thinner in western Marion County and thicker in central Marion County. The uppermost Silurian unit is the Salina Undifferentiated Group that 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 also tend to thin to the west and thicken to the east. The uppermost carbonate units are the fossiliferous Columbus and Delaware Limestones. These rocks were deposited in warm, high-energy seas and reef areas. Rocks belonging to these formations comprise the uppermost carbonate bedrock unit in east central Marion County.

Devonian age Ohio and Olentangy Shale (ODNR, Division of Water, Bedrock State Aquifer Map, 2000) underlies eastern Marion 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.

Mississippian age rocks show a shift to deltaic, fluvial, and shoreline deposits. The oldest Mississippian unit is the Bedford Shale that is limited to eastern Tully Township. It is comprised of very fine-grained silt and clay particles deposited in the outer (distal) margins of a delta. The Bedford Shale is the youngest bedrock unit encountered in Marion County.

Ground Water Resources

Ground water in Marion County is obtained from both unconsolidated (glacial-alluvial) and consolidated (bedrock) aquifers. Thin lenses of sand and gravel interbedded with till primarily comprise the glacial aquifers in Marion County. These thin sand and gravel aquifers are commonly associated with ground moraine deposits in eastern Marion County. Sand and gravel deposits are more commonly utilized in areas with underlying shale bedrock. The carbonate aquifer is an important regional aquifer for most of northwestern Ohio and occupies the western and central portions of Marion County. Yields from shales are typically low and are marginal for supplying even domestic needs. Completed water wells typically penetrate multiple bedrock units.

Yields exceeding 100 gpm (ODNR, Div. of Water, Open File, Bedrock State Aquifer Map, 2000, ODNR, Div. of Water, 1970, and Crowell, 1979) are available from deep, larger diameter wells drilled into the Silurian Salina Undifferentiated Group, the Tymochtee and Greenfield Dolomites, and the Lockport Dolomite. These formations extend across the western and central portions of the county. Yields for the Devonian Columbus and Delaware Limestones vary from 5-100 gpm (ODNR, Div. of Water, Open File, Bedrock State Aquifer Map, 2000, ODNR, Div. Of Water, 1970, and Crowell, 1979). The trend of increasing yields in deeper wells drilled into the carbonates is a generalization. The amount of fracturing, solution, and vuggy (porous) zones has great local importance. Deeper wells are also more likely to contain highly mineralized water and have objectionable water quality. In east central Marion County, wells may be drilled through the shale into the underlying carbonate aquifers to utilize the increased yield. The carbonate aquifers that underlie the thick sequence of shales in eastern Marion County may not be desirable (ODNR, Div. of Water, Open File, Bedrock State Aquifer Map, 2000) due to poor water quality. Water underlying the shale tends to be very high in sulfur, hydrogen sulfide, and iron.

The Devonian Ohio and Olentangy Shales in eastern Marion County are a poor source of ground water. Yields are typically under 5 gpm (ODNR, Div. of Water, Open File, Bedrock State Aquifer Map, 2000 and Crowell, 1979). Typically, the uppermost 10 to 15 feet of the shale is weathered and broken and provides the most water. Wells drilled deeper into the shale provide increased well storage, but typically little additional water. The water quality becomes more objectionable with depth. Yields from the Mississippian Bedford Shale in eastern Tully Township are also typically less than 5 gpm (ODNR, Div. of Water, Open File, Bedrock State Aquifer Map, 2000 and Crowell, 1979).

Yields from sand and gravel lenses interbedded with the fine-grained till averages 5 to 25 gpm (ODNR, Div. of Water, Glacial State Aquifer Map, 2000 and Crowell, 1979). The sand and gravel may also directly overlie the bedrock and yield 5 to 25 gpm. The drillers may penetrate the bedrock directly below the sand and gravel. In such cases the bedrock acts as a “screen” to help filter fines out of the gravel. Sand and gravel lenses are most commonly associated with areas of ground moraine in eastern Marion County. It is important to note that sand and gravel wells are much more commonly utilized in eastern Marion County as the underlying shale is a much poorer aquifer than the carbonates to the west or sandstones to the southeast.

Well log records in south central Marion County show that most wells pass through the sand and gravel outwash and kame deposits and utilize the underlying carbonate bedrock. The outwash deposits commonly are relatively thin. The entire thickness of many of the kame and kame terrace deposits lies above the water table. Also, where the outwash deposits tend to be a bit thicker, such as near Prospect, they contain appreciable amounts of fine sand and silts which make it difficult to construct, develop and complete wells in these materials.

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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 7,200 water well log records are on file for Marion County. Data from roughly 925 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 Marion County* (Crowell, 1979) provided generalized depth to water information throughout the county. Depth to water trends mapped in adjoining Crawford County (Angle and Russell, 2003) was used as a guideline. Topographic and geomorphic trends were utilized in areas where other sources of data were lacking.

Depths to water of 0 to 5 (10) were used for some limited floodplain areas adjacent to the headwaters of some minor streams. Depths of 5 to 15 feet (9) were selected for most of the alluvial settings, ground moraine, intermorainal lakes and areas with shale bedrock aquifers. Depths to water of 15 to 30 feet (7) were used for most areas in the western and central part of the county. Depths to water of 30 to 50 feet (5) were utilized for some of the 7Ac-Till over Limestone settings in the western quarter of the county. The overlying cover of glacial till was thicker in most of these areas. The majority of the end moraines also had depths to water of 30 to 50 feet (5). Depths to water of 50 to 75 feet (3) were utilized for some limited deeper limestone aquifers underlying end moraines in the western portion of the county.

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. Recharge ratings from neighboring Crawford County (Angle and Russell, 2003) were used as a guideline. Some localized recharge data was included in the investigation for the Superconducting Super Collider (SSC) site in Ohio (Ohio SSC-State of Ohio, 1987)

Values of 4 to 7 inches per year (6) were used for areas with moderate recharge. These areas include all of the alluvial settings in the county, most areas of ground moraine, and all of the end moraines. Values of 2 to 4 inches per year (3) were utilized for most areas associated with intermorainal lakes and for the deeper bedrock aquifers of the 7Aa- Glacial Till over Interbedded Limestone and Shale hydrogeologic setting.

Aquifer Media

Information on evaluating aquifer media was obtained primarily from the *Ground Water Resources of Marion County* (Crowell, 1979). 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 ratings from neighboring Crawford County (Angle and Russell, 2003) were used as a guideline. The ODNR, Division of Water, Glacial State Aquifer Map and Bedrock State Aquifer Map (2000) were an important source of aquifer data. The *Glacial Geology of Marion County* (Totten, 1986), 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 of the Div. of Water (1970) on carbonate rocks in Northwestern Ohio. Additional aquifer information was obtained from the investigation for the proposed Superconducting Super Collider (SSC) site in Ohio (Ohio SSC-State of Ohio, 1987). Well log records on file at the ODNR, Division of Water, were the primary source of aquifer information.

All of the bedrock and most of the interbedded lenses of sand and gravel are semi-confined or leaky; however for the purposes of DRASTIC, they have been evaluated as being unconfined (Aller et al., 1987). Massive limestone was evaluated as the aquifer in the 7Ac-Glacial Till over Limestone and in adjacent settings with carbonate aquifers. A rating of (7) was applied to the Silurian and Devonian limestones that comprise the aquifer in western and central Marion County. An aquifer rating of (3) was utilized for shale aquifers in eastern Marion County.

Sand and gravel aquifers elsewhere were assigned a rating of (6) or (5) depending upon how clean, coarse and thick the deposits were. 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 Marion County* (Miller and Martin, 1989). 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 Marion County showed a high degree of variability. This is a reflection of the parent material. Table 10 is a list of the soils, parent materials, setting, and corresponding DRASTIC values for Marion County.

Soils were rated as Thin/Absent (10) in some limited areas adjacent to quarries where limestone was very near the ground surface. Shrink-swell (non-aggregated) clays (7) were selected for some thick, highly clayey lacustrine soils. Soils were considered to be sandy

Table 10. Marion County soils

Soil Name	Parent Material/ Setting	DRASTIC Rating	Soil Media
Bennington	Clayey till	3	Clay loam
Blount	Loamy till	3	Clay loam
Cardington	Clayey till	3	Clay loam
Centerburg	Loamy Till	3	Clay loam
Del Rey	Lacustrine	3	Clay loam
Elliot	Clayey till	3	Clay loam
Fitchville	Deltaic, lacustrine	4	Silt loam
Fox	Outwash, kames	6	Sandy loam
Fulton	Clayey lacustrine	7	Shrink-swell clay
Glynwood	Clayey till	3	Clay loam
Kendallville	Silty Till	3	Clay loam
Latty	Clayey lacustrine	7	Shrink-swell clay
Martinsville	Sandy shoreline, delta	6	Sandy loam
Medway	Alluvium	4	Silt loam
Milford	Alluvium	4	Silt loam
Milton	Thin till over limestone	10	Thin/Absent
Muskego	Kettle, bogs	8	Peat
Newark	Alluvium	4	Silt Loam
Nolin	Alluvium	4	Silt loam
Ockley	Outwash, kame along moraines	6	Sandy Loam
Paulding	Clayey lacustrine	7	Shrink-swell clay
Pewamo	Clayey till	3	Clay loam
Saranac	Alluvium, slackwater	3	Clay loam
Shinrock	Lacustrine	3	Clay loam
Sleeth	Outwash, coarse alluvium	6	Sandy loam
Sloan	Alluvium	4	Silt loam
Westland	Outwash, kame	6	Sandy loam
Whitaker	Outwash,shoreline,deltaic	6	Sandy loam

loam (6) for exposures of outwash/kame sand and gravel deposits and some minor coarse shoreline/deltaic deposits bordering intermorainal lakes. Loam (5) and silt loam (4) were designated for alluvial and floodplain deposits. Clay loam (3) soils were evaluated for the majority of the county including till overlying ground moraine and end moraine and lacustrine deposits associated with the intermorainal lakes. For the purposes of determining the hydrogeologic setting, clay loam soils were differentiated as to whether they overly ground moraine versus intermorainal lakes.

Topography

Topography, or percent slope, was evaluated using U.S.G.S. 7-1/2 minute quadrangle maps and the *Soil Survey of Marion County* (Miller and Martin, 1989). Slopes of 0 to 2 percent (10) were selected for almost all of the settings in Marion County due to the overall flat lying to gently rolling topography and low relief. Slopes of 2 to 6 percent (9) were assigned to most end moraines exhibiting hummocky terrain. Slopes of 6 to 12 percent (5) were selected for a limited number of areas where the Scioto River or Olentangy River have steeply downcut the surrounding end moraine or ground moraine in southern Marion County.

Impact of the Vadose Zone Media

Information on evaluating vadose zone media was obtained primarily from the *Ground Water Resources of Marion County* (Crowell, 1979). 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 neighboring Crawford County (Angle and Russell, 2003) were used as a guideline. The ODNR, Division of Water, Glacial State Aquifer Map and Bedrock State Aquifer Map (2000) were an important source of vadose zone media data. The *Soil Survey of Marion County* (Miller and Martin, 1989) provided valuable information on parent materials. The *Glacial Geology of Marion County* (Totten, 1986), 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. Additional vadose zone media information was obtained from the investigation for the proposed Superconducting Super Collider (SSC) site in Ohio (Ohio SSC-State of Ohio, 1987). Water well log records on file at the ODNR, Division of Water, were the primary source of vadose zone information.

The vadose zone media is a critical component of the overall DRASTIC rating in Marion 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.

Limestone with a vadose zone media rating of (7) was selected for parts of central Marion County where the till covering the underlying limestone was very thin. Shale was assigned a vadose zone media rating of (3) for limited areas in southeastern Marion County where the till covering the underlying shale was very thin. The vadose zone media for the 7Aa - Till over Interbedded Limestone and Shale was selected as a combination of shale and till (3) together as wells are drilled through both of these thick units into the underlying limestone. The rating of (3) is indicative of the semi-confined (but not truly confined nature of the underlying limestone. This hydrogeologic setting is limited to portions of eastern Marion County adjacent to the Olentangy River.

A vadose zone media rating of (5) or (6) was chosen for sand and gravel with significant silt and clay for alluvial and outwash terraces flanking the Scioto River in southern Marion County. Till with a vadose zone media rating of (6) was selected for portions of the St. Johns Moraine in southwestern Marion County where the till is sandier and contains numerous sand and gravel lenses. Till with a vadose zone media rating of (5) was selected for most areas of end moraine and ground moraine in Marion County. Till with a vadose zone media rating of (4) was assigned to till in areas of ground moraine where the till was believed to be finer-grained or thicker. Silt and clay with a vadose zone media rating of (5) was selected for most alluvial settings in the county. Silt and clay with a rating of (4) was applied to most areas occupied by intermorainal lakes. Silt and clay with a rating of (3) was selected for intermorainal lakes that were especially clayey. Shrink-swell (non-aggregated) clay soils developed from these clayey sediments.

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 Marion County* (Crowell, 1979). 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 neighboring Crawford County (Angle and Russell, 2003) were used as a guideline. The ODNR, Division of Water, Glacial State Aquifer Map and Bedrock State Aquifer Map (2000) were an important source of hydraulic conductivity data. Extensive hydraulic conductivity data was obtained from the investigation for the proposed Superconducting Super Collider (SSC) site in Ohio (Ohio SSC-State of Ohio, 1987). 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 aquifers.

Values for hydraulic conductivity correspond to aquifer ratings; i.e., the more highly rated aquifers have higher values for hydraulic conductivity. All of the sand and gravel aquifers were assigned a hydraulic conductivity rating of 300-700 (4) gallons per day per square foot (gpd/ft^2). The majority of the limestone aquifers were also assigned a hydraulic conductivity range of 300-700 gpd/ft^2 (4). A limited number of high-yielding limestone aquifers adjacent to the Scioto River were given a hydraulic conductivity rating of 700-1000 gpd/ft^2 (6) due to the high amount of fracturing and jointing nature. A hydraulic conductivity rating of 1-100 gpd/ft^2 (1) was selected for all shale aquifers.

APPENDIX B

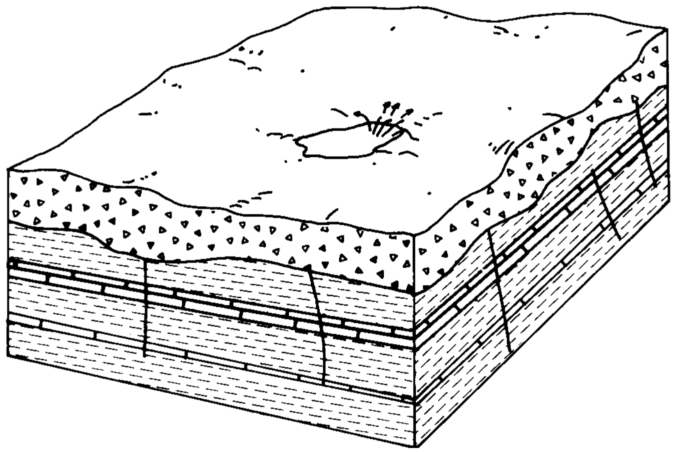
DESCRIPTION OF HYDROGEOLOGIC SETTINGS AND CHARTS

Ground water pollution potential mapping in Marion 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 11. Computed pollution potential indexes for Marion County range from 105 to 167.

Table 11. Hydrogeologic settings mapped in Marion County, Ohio

Hydrogeologic Settings	Range of GWPP Indexes	Number of Index Calculations
7 Aa-Glacial till over interbedded limestone and shale	106-121	4
7 Ac-Glacial till over limestone	106-159	20
7 Ae-Glacial till over shale	105-122	6
7Af-Sand and gravel interbedded in glacial till	110-146	13
7 C-Moraine	107-143	11
7 Ec-Alluvium over sedimentary rock	124-155	18
7 Ed-Alluvium over glacial till	135-142	5
7 Fc-Intermorainal lake deposits	105-138	13
7Gb-Thin till over limestone	157-167	2

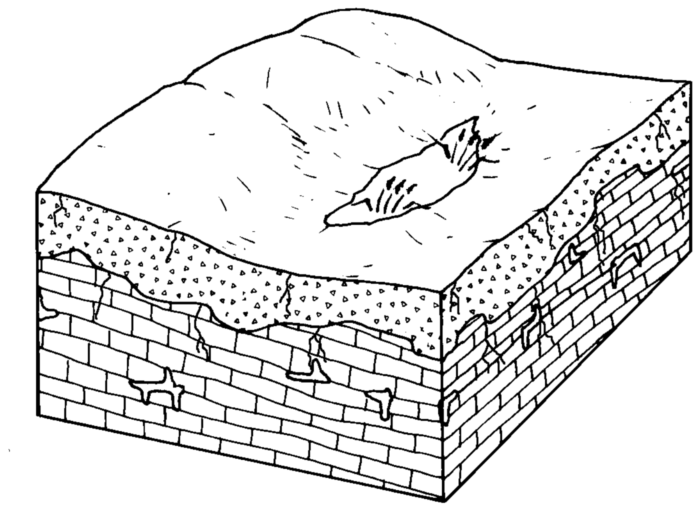
The following information provides a description of each hydrogeologic setting identified in the county, a block diagram illustrating the characteristics of the setting, and a listing of the charts for each unique combination of pollution potential indexes calculated for each setting. The charts provide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



7Aa-Glacial Till over Interbedded Limestone and Shale

This hydrogeologic setting is limited to the east central portion of Marion County and roughly parallels the Olentangy River. The area is characterized by flat lying to gently rolling topography and low relief. The vadose zone is composed of a combination of clayey glacial till and black shale. The till may be fractured or jointed, particularly in areas where it is predominantly thin and weathered. The shale may also be fractured. Depth to water is commonly shallow, averaging less than 35 feet. Soils are generally clay loams. The aquifer is the underlying limestone. Yields from the bedrock typically range from 5 to 25 gpm. Recharge is moderately low due to the impermeable nature of the soils and vadose zone.

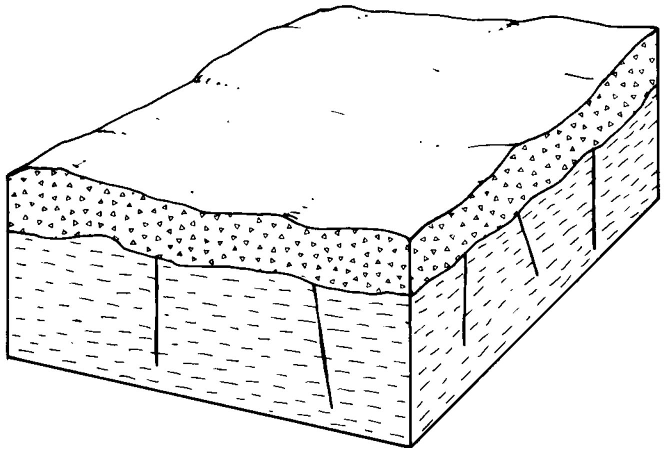
GWPP index values for the hydrogeologic setting of Glacial Till over Interbedded Limestone and Shale range from 106 to 121, with the total number of GWPP index calculations equaling 4.



7Ac-Glacial Till over Limestone

This hydrogeologic setting is widespread in western and central Marion County. The area is characterized by the flat-lying topography and very low relief associated with ground moraine. 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 the vadose zone media. The aquifer is composed of fractured Silurian and/or Devonian limestones and dolomites. These carbonate rocks may contain significant solution features. Depth to water is typically shallow to moderate, ranging from 15 to 50 feet. Soils are variable but 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. Yields range from 5 to 100 gpm for the Devonian carbonate units. Recharge is moderate to low due to the clayey nature of the soils and vadose zone and the relatively shallow depth to water.

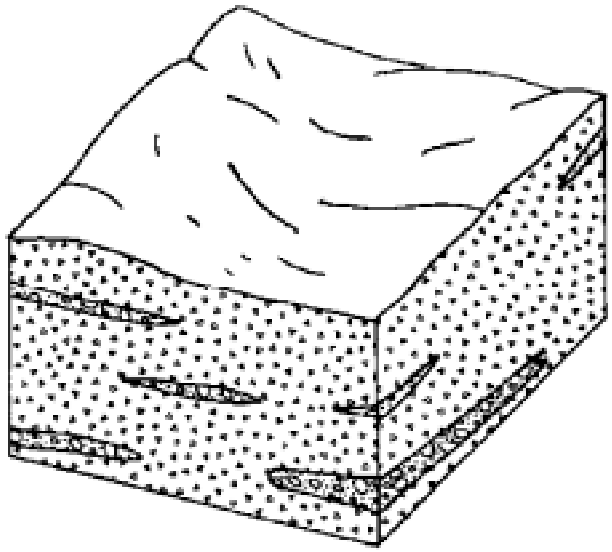
GWPP index values for the hydrogeologic setting of Glacial Till over Solution Limestone range from 106 to 159, with the total number of GWPP index calculations equaling 20.



7Ae-Glacial Till over Shale

This hydrogeologic setting is found in eastern Marion County. The area is characterized by the flat-lying topography and very low relief associated with ground moraine. The vadose zone is composed of clayey glacial till. In a few areas where the till is very thin, shale bedrock is the vadose media. The till may be fractured or jointed, particularly in areas where it is predominantly thin and weathered. Depth to water is typically shallow, averaging less than 20 feet. Soils are generally clay loams. The aquifer is usually fractured, massive black Devonian-age shale or fine-grained, silty Mississippian Bedford Shale. Yields from the shale are typically less than 5 gpm. Recharge is moderately low due to the clayey vadose zone and soils and the impermeable nature of the shale bedrock.

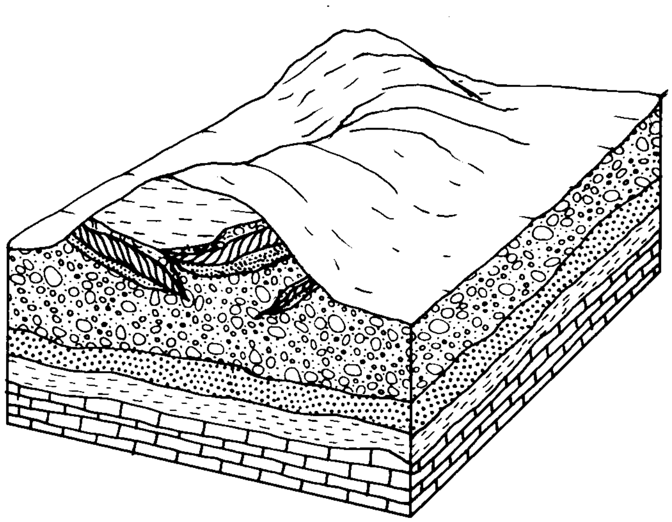
GWPP index values for the hydrogeologic setting of Glacial Till over Shale range from 105 to 122, with the total number of GWPP index calculations equaling 6.



7Af-Sand and Gravel Interbedded in Glacial Till

This hydrogeologic setting is limited to eastern Marion County. The underlying bedrock is low-yielding shale, making the sand and gravel aquifers more attractive. The area is characterized by flat lying topography and low relief. The setting is commonly associated with areas of ground moraine. 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 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 moderately low due to the relatively low permeability of the clayey soils and vadose zone material.

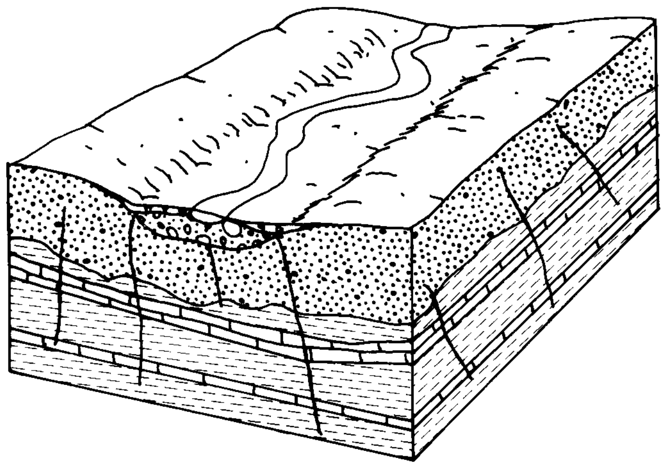
GWPP index values for the hydrogeologic setting of Sand and Gravel Interbedded in Glacial Till range from 110 to 146, with the total number of GWPP index calculations equaling 13.



7C-Moraine

This hydrogeologic setting consists of segments of the numerous end moraines that cross Marion County. This setting is characterized by hummocky to rolling topography. Relief tends to become steeper near the margins of the moraine, especially if enhanced by the downcutting of an adjacent stream. The aquifer consists of relatively thin sand and gravel lenses interbedded with glacial till within the moraine. These sand and gravel deposits differ as to lateral extent and thickness and are found at variable depths. Yields range from 5 to 25 gpm. If sand and gravel lenses are not encountered or if they are too thin, wells are completed in the underlying bedrock. This is very common in central and western Marion County where the underlying bedrock is high-yielding limestone. The vadose zone is composed of loamy 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 variable and depends primarily upon how deep the underlying aquifer is. Soils are commonly clay loams. Recharge is moderately high due to the proximity of sand and gravel lenses to the surface and the amount of weathering and fracturing in the till. The end moraines are the primary local sources of recharge. End moraine deposits tend to be coarser than those of the surrounding ground moraine; therefore, these deposits will tend to store and transmit water more readily than the ground moraine. Overall, the St. Johns Moraine contains more sand and gravel than the Wabash Moraine.

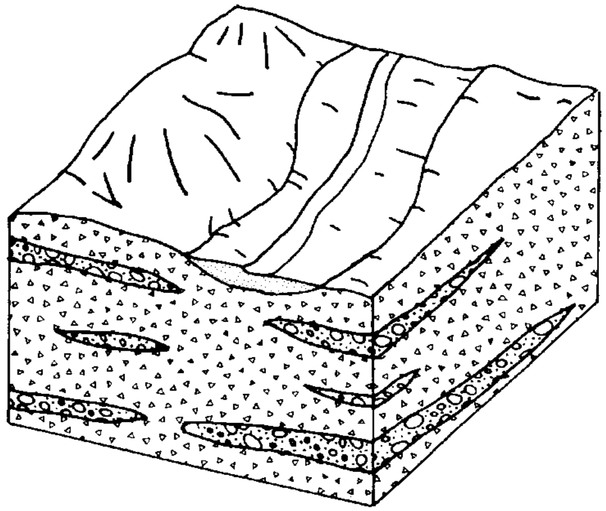
GWPP index values for the hydrogeologic setting of Moraine range from 107 to 143, with the total number of GWPP index calculations equaling 11.



7Ec-Alluvium over Sedimentary Rock

This hydrogeologic setting is common throughout western and central Marion County. 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 7Ed-Alluvium over Glacial Till except that the underlying aquifers consist of bedrock. The aquifers in western and central Marion County are limestone; in northeastern Marion County, shale is the aquifer. The vadose zone consists of the sandy to silty to clayey alluvial deposits. 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. Yields vary, depending upon the type of underlying bedrock. Recharge is typically moderately high due to the flat-lying topography, shallow depth to water, the moderate permeability of the soils, and the varying permeability of the underlying bedrock.

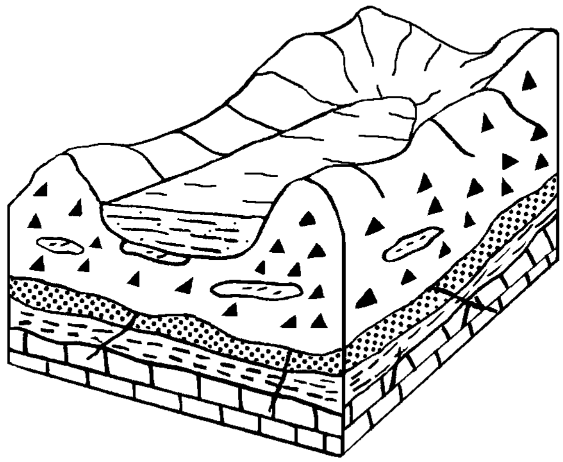
The GWPP index values for the hydrogeologic setting Alluvium over Sedimentary Rocks range from 124 to 155, with the total number of GWPP index calculations equaling 18.



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. The setting is also similar to the 7Ec-Alluvium over Sedimentary Rock except that the underlying aquifer consists of shallow sand and gravel lenses instead of bedrock. The stream may or may not be in direct hydraulic connection with the underlying sand and gravel lenses that constitute the aquifer. The surficial, silty alluvium is typically more permeable than the underlying till. The alluvium is too thin to be considered the aquifer. The vadose zone consists of the silty to clayey alluvial deposits. Soils are silt loams or clay loams. Yields commonly range from 5 to 25 gpm from the sand and gravel lenses. Depth to water is typically shallow with depths averaging less than 20 feet. Recharge is moderately high due to the shallow depth to water, flat-lying topography, and the moderate permeability of the glacial till and alluvium.

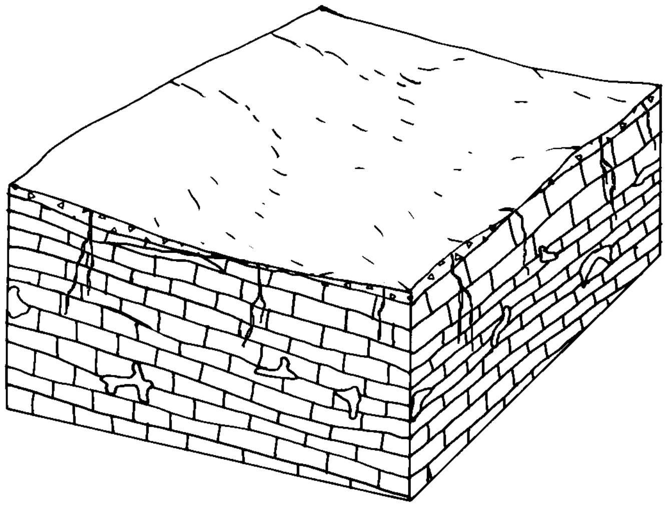
The GWPP index values for the hydrogeologic setting Alluvium Over Glacial Till range from 135 to 142, with the total number of GWPP index calculations equaling 5.



7Fc-Intermorainal Lake Deposits

This hydrogeologic setting is characterized by the flat-lying topography between end moraines and contains varying thicknesses of fine-grained lacustrine sediments. Surficial drainage is typically very poor; ponding is very common after rains. These sediments were deposited in shallow lakes formed between end moraines and the retreating ice sheets before the modern drainage system evolved. This setting occupies many of the low-lying areas within northern Marion County. The vadose zone media consists of silty to clayey lacustrine sediments that overlie glacial till. The aquifer consists of thin sand and gravel lenses interbedded in the underlying till or the underlying bedrock. Yields are usually 5 to 25 gpm for the sand and gravel lenses and sandstones, and over 25 gpm for the limestones. Depth to water is commonly very shallow. Soils are clay loams derived from clayey lacustrine sediments. Some of the very high clay content lacustrine sediments weather into shrink-swell (non-aggregated) clay soils. Recharge in this setting is low due to the relatively low permeability soils and vadose zone material.

GWPP index values for the hydrogeologic setting of Intermorainal Lake Deposits range from 105 to 138, with the total number of GWPP index calculations equaling 13.



<u>7Gb-Thin Till over Limestones</u>

This hydrogeologic setting is characterized by flat-lying topography and is adjacent to limestone quarries in north central Marion County. The overlying glacial till is patchy, thin, and may be totally absent in some areas. Any remaining glacial till is thin and highly weathered and fractured. Soils are considered to be Thin/Absent. Depth to water is commonly shallow. Fractured limestone is the vadose zone media. Recharge to the underlying limestone is fairly high due to bedrock being exposed at the surface.

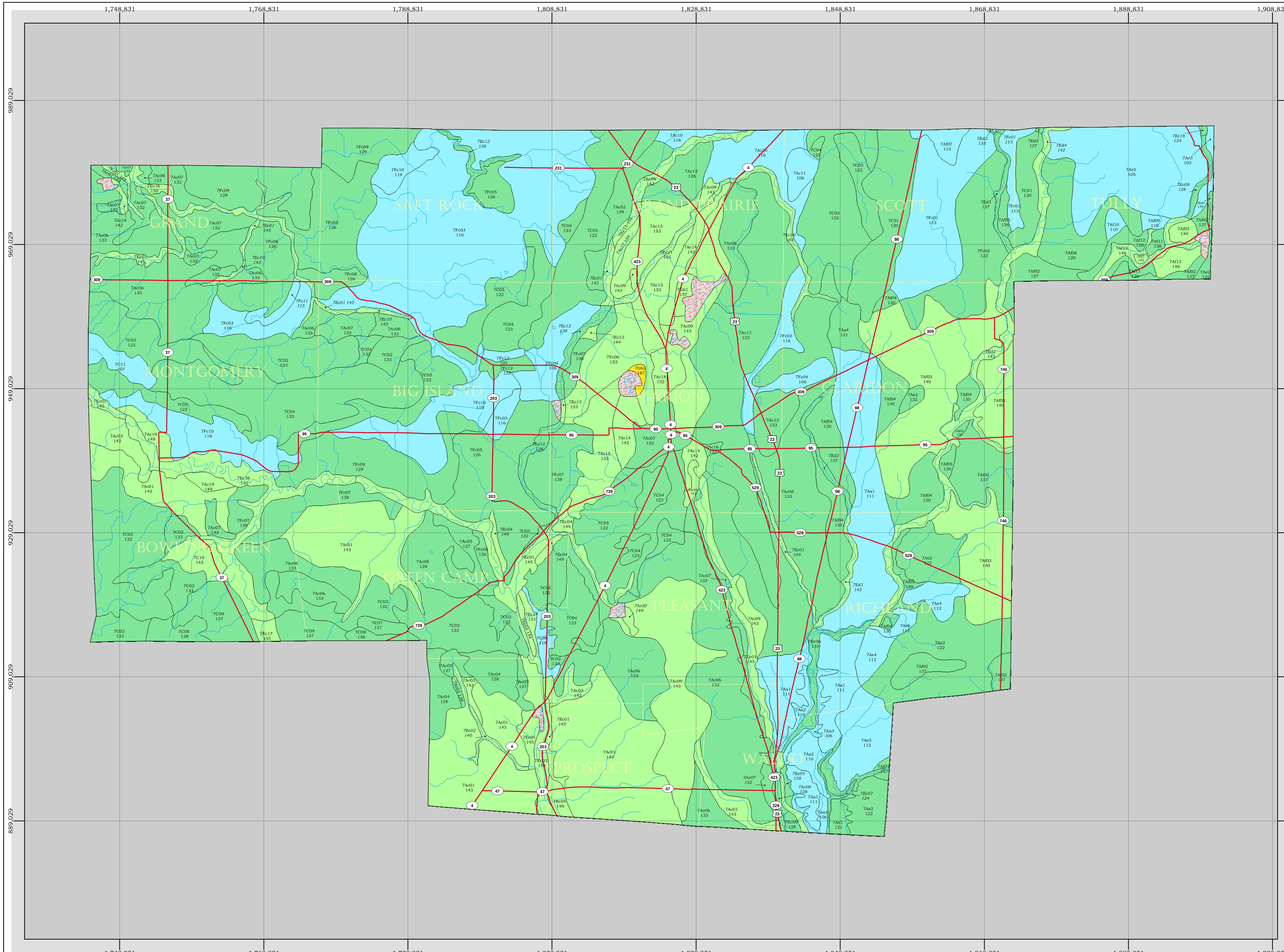
GWPP index values for the hydrogeologic setting of Thin Till over Limestone range from 157 to 167, with the total number of GWPP index calculations equaling 2.

Table 12. Hydrogeologic Settings, DRASTIC Factors, and Ratings

Setting	Depth to Water	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% Slope)	Vadose Zone Media	Hydraulic Conductivity	Rating	Pesticide Rating
7Aa1	15-30	2-4	limestone	Clay Loam	0-2	shale + till	300-700	111	133
7Aa2	15-30	2-4	limestone	Clay Loam	2-6	shale + till	300-700	110	130
7Aa3	15-30	2-4	limestone	Clay Loam	6-12	shale + till	300-700	106	118
7Aa4	5-15	2-4	limestone	Clay Loam	0-2	shale + till	300-700	121	143
7Ac01	5-15	4-7	limestone	Clay Loam	0-2	till	300-700	143	163
7Ac02	15-30	4-7	limestone	Sandy Loam	0-2	till	300-700	139	168
7Ac03	5-15	4-7	limestone	Clay Loam	2-6	till	300-700	142	160
7Ac04	15-30	4-7	limestone	Clay Loam	0-2	till	300-700	128	149
7Ac05	15-30	4-7	limestone	Clay Loam	2-6	till	300-700	127	146
7Ac06	15-30	4-7	limestone	Clay Loam	0-2	till	300-700	133	153
7Ac07	15-30	4-7	limestone	Clay Loam	2-6	till	300-700	132	150
7Ac08	15-30	4-7	limestone	Clay Loam	6-12	till	300-700	128	138
7Ac09	15-30	4-7	limestone	Clay Loam	0-2	limestone	300-700	143	161
7Ac10	15-30	2-4	limestone	Clay Loam	0-2	till	300-700	116	137
7Ac11	30-50	2-4	limestone	Clay Loam	0-2	till	300-700	106	127
7Ac12	5-15	2-4	limestone	Clay Loam	0-2	till	300-700	126	147
7Ac13	30-50	4-7	limestone	Clay Loam	0-2	till	300-700	123	143
7Ac14	15-30	4-7	limestone	Clay Loam	2-6	limestone	300-700	142	158
7Ac15	5-15	4-7	limestone	Clay Loam	0-2	limestone	300-700	153	171
7Ac16	30-50	4-7	limestone	Clay Loam	0-2	limestone	300-700	133	151
7Ac17	5-15	4-7	limestone	Sandy Loam	0-2	limestone	300-700	159	186
7Ac18	5-15	4-7	limestone	Clay Loam	2-6	limestone	300-700	152	168
7Ac19	5-15	4-7	limestone	Sandy Loam	0-2	till	300-700	149	178
7Ac20	15-30	4-7	limestone	Sandy Loam	0-2	limestone	300-700	149	176
7Ae1	5-15	4-7	shale	Clay Loam	2-6	till	1-100	121	142
7Ae2	5-15	4-7	shale	Clay Loam	0-2	till	1-100	122	145
7Ae3	15-30	4-7	shale	Clay Loam	0-2	till	1-100	112	135
7Ae4	5-15	4-7	shale	Clay Loam	0-2	shale	1-100	112	137
7Ae5	5-15	2-4	shale	Clay Loam	0-2	till	1-100	105	129
7Ae6	15-30	4-7	shale	Clay Loam	2-6	till	1-100	111	132
7Af01	15-30	4-7	sand + gravel	Clay Loam	0-2	till	300-700	127	147
7Af02	5-15	4-7	sand + gravel	Clay Loam	0-2	till	300-700	137	157
7Af03	5-15	4-7	sand + gravel	Clay Loam	0-2	till	300-700	140	160
7Af04	15-30	4-7	sand + gravel	Clay Loam	0-2	till	300-700	130	150
7Af05	5-15	4-7	sand + gravel	Clay Loam	2-6	till	300-700	139	157
7Af06	15-30	4-7	sand + gravel	Sandy Loam	0-2	till	300-700	136	165

Setting	Depth to Water	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% Slope)	Vadose Zone Media	Hydraulic Conductivity	Rating	Pesticide Rating
7Af07	15-30	2-4	sand + gravel	Clay Loam	0-2	till	300-700	113	134
7Af08	5-15	2-4	sand + gravel	Clay Loam	0-2	till	300-700	120	141
7Af09	5-15	2-4	sand + gravel	Clay Loam	2-6	till	300-700	119	138
7Af10	15-30	2-4	sand + gravel	Clay Loam	0-2	till	300-700	110	131
7Af11	5-15	4-7	sand + gravel	Clay Loam	2-6	till	300-700	136	154
7Af12	15-30	4-7	sand + gravel	Clay Loam	2-6	till	300-700	126	144
7Af13	5-15	4-7	sand + gravel	Sandy Loam	0-2	till	300-700	146	175
7C01	15-30	4-7	sand + gravel	Clay Loam	0-2	till	300-700	130	150
7C02	15-30	4-7	limestone	Clay Loam	0-2	till	300-700	133	153
7C03	15-30	4-7	limestone	Clay Loam	2-6	till	300-700	132	150
7C04	30-50	4-7	limestone	Clay Loam	0-2	till	300-700	123	143
7C05	30-50	4-7	limestone	Clay Loam	2-6	till	300-700	122	140
7C06	30-50	4-7	limestone	Clay Loam	6-12	till	300-700	118	128
7C07	30-50	4-7	limestone	Clay Loam	2-6	till	300-700	127	144
7C08	15-30	4-7	limestone	Clay Loam	0-2	till	300-700	138	157
7C09	15-30	4-7	limestone	Clay Loam	2-6	till	300-700	137	154
7C10	5-15	4-7	limestone	Clay Loam	0-2	till	300-700	143	163
7C11	50-75	4-7	limestone	Clay Loam	2-6	till	300-700	107	126
7Ec01	5-15	4-7	limestone	Silty Loam	0-2	silt/clay	300-700	145	168
7Ec02	5-15	4-7	limestone	Silty Loam	0-2	silt/clay	300-700	140	164
7Ec03	5-15	4-7	limestone	Sandy Loam	0-2	sd+gvl w/silt+clay	700-1000	155	182
7Ec04	5-15	4-7	limestone	Sandy Loam	0-2	sd+gvl w/silt+clay	300-700	149	178
7Ec05	15-30	4-7	limestone	Sandy Loam	2-6	sd+gvl w/silt+clay	300-700	138	165
7Ec06	5-15	4-7	limestone	Silty Loam	0-2	shale + till	300-700	135	160
7Ec07	5-15	4-7	shale	Silty Loam	0-2	silt/clay	1-100	124	150
7Ec08	0-5	4-7	shale	Sandy Loam	0-2	silt/clay	1-100	128	161
7Ec09	5-15	4-7	limestone	Loam	0-2	silt/clay	300-700	142	169
7Ec10	5-15	4-7	limestone	Clay Loam	0-2	silt/clay	300-700	143	163
7Ec11	5-15	4-7	limestone	Silty Loam	0-2	limestone	300-700	155	176
7Ec12	5-15	4-7	limestone	Clay Loam	0-2	silt/clay	300-700	138	159
7Ec13	5-15	4-7	limestone	Sandy Loam	0-2	silt/clay	300-700	144	174
7Ec14	5-15	4-7	limestone	Silty Loam	0-2	silt/clay	700-1000	151	172
7Ec15	5-15	4-7	limestone	Clay Loam	0-2	limestone	300-700	153	171
7Ec16	0-5	4-7	limestone	Silty Loam	0-2	silt/clay	300-700	150	173
7Ec17	0-5	4-7	limestone	Silty Loam	0-2	sd+gvl w/silt+clay	300-700	155	177
7Ec18	0-5	4-7	shale	Silty Loam	0-2	silt/clay	1-100	124	151
7Ed1	5-15	4-7	sand + gravel	Silty Loam	0-2	silt/clay	300-700	142	165
7Ed2	5-15	4-7	sand + gravel	Clay Loam	0-2	silt/clay	300-700	135	156

Setting	Depth to Water	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% Slope)	Vadose Zone Media	Hydraulic Conductivity	Rating	Pesticide Rating
7Ed3	5-15	4-7	sand + gravel	Silty Loam	0-2	silt/clay	300-700	137	161
7Ed4	0-5	4-7	sand + gravel	Silty Loam	0-2	silt/clay	300-700	142	166
7Ed5	5-15	4-7	sand + gravel	Silty Loam	0-2	silt/clay	300-700	139	162
7Fc01	15-30	2-4	sand + gravel	Clay Loam	0-2	silt/clay	300-700	113	134
7Fc02	5-15	2-4	sand + gravel	Clay Loam	0-2	silt/clay	300-700	123	144
7Fc03	15-30	2-4	limestone	Clay Loam	0-2	silt/clay	300-700	116	137
7Fc04	30-50	2-4	limestone	Clay Loam	0-2	silt/clay	300-700	106	127
7Fc05	5-15	2-4	limestone	Clay Loam	0-2	silt/clay	300-700	126	147
7Fc06	5-15	4-7	limestone	Clay Loam	0-2	limestone	300-700	153	171
7Fc07	5-15	4-7	limestone	Clay Loam	0-2	silt/clay	300-700	138	159
7Fc08	5-15	2-4	limestone	Clay Loam	0-2	silt/clay	300-700	126	147
7Fc09	5-15	2-4	limestone	Shrink/Swell Clay	0-2	silt/clay	300-700	129	163
7Fc10	15-30	2-4	limestone	Shrink/Swell Clay	0-2	silt/clay	300-700	119	153
7Fc11	15-30	2-4	limestone	Clay Loam	2-6	silt/clay	300-700	115	134
7Fc12	5-15	2-4	limestone	Clay Loam	2-6	silt/clay	300-700	125	144
7Fc13	30-50	2-4	limestone	Clay Loam	2-6	silt/clay	300-700	105	124
7Gb1	15-30	4-7	limestone	Thin/Absent	0-2	limestone	300-700	157	196
7Gb2	5-15	4-7	limestone	Thin/Absent	0-2	limestone	300-700	167	206



Ground Water Pollution Potential of Marion County

by

Mike Angle, Ohio Department of Natural Resources

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 wtih 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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