GROUND WATER POLLUTION POTENTIAL OF HARDIN COUNTY, OHIO

BY

MICHAEL HALLFRISCH

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ABSTRACT

A ground water pollution potential map of Hardin 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 Hardin County resulted in a map with symbols and colors, which illustrate areas of varying ground water pollution potential indexes ranging from 99 to 168.

Hardin County lies entirely within the Glaciated Central hydrogeologic setting. Limestones and dolomites of the Silurian System compose the aquifer for most of the county. Yields of 25 to over 500 gallons per minute (gpm) are possible from properly designed, large diameter wells penetrating deep into this aquifer.

Deep layers of sand and gravel are utilized as the aquifer in the main trunk of the deep buried valley system found in the west-central and southwestern portions of Hardin County. This buried valley system is part of the ancient Teays River valley system. Yields over 100 gpm are possible from properly designed large diameter wells completed in some portions of the buried valley.

Wells completed in the three end moraines that traverse the county may encounter sand and gravel lenses in sufficient thickness to supply domestic or small farm wells (5 to 25 gpm). Few wells in Hardin County obtain their supply from sand and gravel interbedded in the glacial ground moraine that mantles most of the county.

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 Hardin 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. 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; 3527 of these wells exist in Hardin 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 Hardin 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 Hardin 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

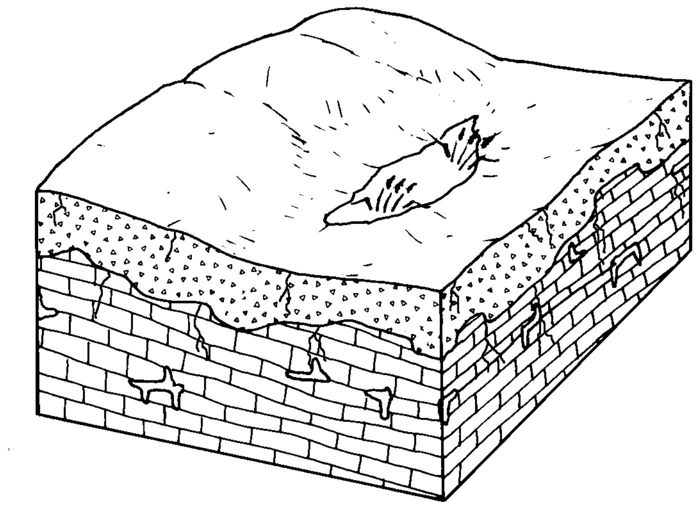
These factors incorporate concepts and mechanisms such as attenuation, retardation, and time or distance of travel of a contaminant with respect to the physical characteristics of the hydrogeologic setting. Broad consideration of these factors and mechanisms coupled with existing conditions in a setting 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 common across Hardin County. Areas with this hydrologic setting are characterized by flat-lying topography and 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 thin and weathered. Where the till is thin (less than 25 feet), fractured limestone along with the till is considered to be the vadose zone media. The aquifer is composed of fractured Silurian 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 typically are clay loams derived from till. Maximum ground water yields greater than 500 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.

GWPP index values for the hydrogeologic setting of Glacial Till over Limestone range from 112 to 162, with the total number of GWPP index calculations equaling 37.

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. As the DRASTIC index increases, so does the aquifer's 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	

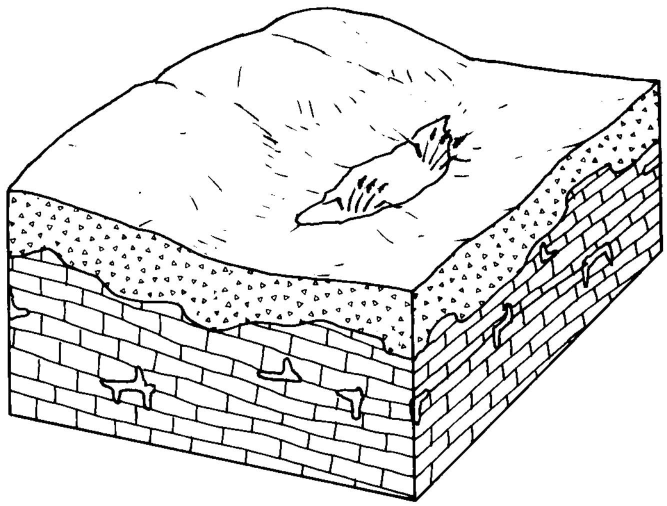
Table 8. Ranges and ratings for hydraulic conductivity

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, Glacial Till over Limestone, identified in mapping Hardin 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 132. 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 Hardin County produces settings with a wide range of vulnerability to ground water contamination. Pollution potential indexes for the eight settings identified in the county range from 99 to 168.

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 Hardin 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 Hardin 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	2-6%	1	9	9
Impact of Vadose Zone	Till	5	5	25
Hydraulic Conductivity	300-700	3	4	12
		DRASTIC	INDEX	132

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
132 - 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 (**132**) 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 HARDIN COUNTY

Demographics

Hardin County occupies approximately 470 square miles (Department of Development, Ohio County Profiles, 2007) in north central Ohio (Figure 3). The county is bounded to the north by Hancock County, to the east by Wyandot and Marion Counties, to the west by Allen and Auglaize Counties, and to the south by Logan and Union Counties.

The approximate population of Hardin County, based upon year 2006 census estimates, is 31,966 (Department of Development, Ohio County Profiles, 2007). Kenton is the largest community and the county seat. Agriculture accounts for roughly 87 percent of the land usage in Hardin 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 degrees Fahrenheit for Hardin County. Harstine (1991) shows that precipitation averages between 34 and 35 inches per year for the county. The mean annual precipitation for Kenton is 35.65 inches per year based upon a thirty-year (1971-2000) period (National Oceanographic and Atmospheric Administration (NOAA), 2002). The mean annual temperature at Kenton for the same thirty-year period is 50 degrees Fahrenheit (NOAA, 2002).

Physiography and Topography

Hardin County lies entirely within the Central Till Plains Lowland Province (Frost, 1931; Fenneman, 1938, and Bier, 1956). Brockman (1998) and Schiefer (2002) depict Hardin County as belonging in the Central Ohio Clayey Till Plain. Hardin County is characterized by flat to gently rolling ground moraine separated by wide belts of hummocky end moraines.

Figure 3. Location map of Hardin County, Ohio.

Modern Drainage

The major drainage divide crossing north central Ohio runs through the middle of Hardin County. The area north of the divide drains towards Lake Erie, while the area south of the divide drains towards the Ohio River. The Blanchard River drains most of north central and northeastern Hardin County, and eventually empties into the Auglaize River. Hog Creek drains the northwestern portion of the county, and it flows into the Ottawa River, which also empties into the Auglaize River. Most of the southern half of the county is drained by the Scioto River, which flows south to empty into the Ohio River.

Pre- and Inter-Glacial Drainage Changes

Prior to Pleistocene glaciation, the drainage system that existed in Ohio is referred to as the Teays Stage. The Teays River drained the southern and western two thirds of the state. The main channel of the Teays River passed just southwest of Hardin County through Champaign, Shelby and Auglaize counties before exiting Ohio in northern Mercer County. A small tributary of the Teays River flowed south through western Hardin and Logan counties and joined the main channel of the Teays in northeastern Shelby County (Schmidt, 1982; 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 partially filled with glacial drift from the advancing ice sheets. Subsequent ice advances during the Illinoian and Wisconsinan periods further filled the former channels. These sediment-filled ancestral valleys are referred to as buried valleys. Slowly, after the Wisconsinan ice retreated, the drainage patterns of Hardin County evolved into the system that exists today. The modern drainage reflects the nature of landforms deposited during the Wisconsinan advances, particularly end moraines.

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. The oldest ice advances, prior to 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 Hardin County. Evidence for earlier glaciations is lacking or obscured on the land surface.

Four main types of unconsolidated (glacial) deposits are found in Hardin County: (glacial) till, lacustrine (lake bottom) deposits, alluvial (river) deposits, ice-contact sand and gravel (kames, eskers) deposits and outwash sand and gravel. Alluvium (alluvial deposits) consists of both ancestral and relatively modern sediments deposited by rivers.

Drift is term that collectively refers to the entire sequence of glacial deposits. Overall, drift is thinner in areas of ground moraine and thickens in end moraines. Drift is thickest in the buried valleys found in western Hardin County. There are several areas in northern Hardin County, between end moraines, where the drift is less than 25 feet thick. (ODNR, Division of Geological Survey, Open File Bedrock Topography, ODNR, Division of Water, Glacial State Aquifer Map, 2000, and ODNR, Division of Water, water well log and drilling reports).

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. 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.

Till has relatively low inherent permeability. Permeability in till is in part dependent upon its primary porosity and the number and size of the connections between the pore spaces. 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 within the till.

Two primary landforms found in Hardin County, ground moraine and end moraine, are composed of till. Ground moraine (till plain) is relatively flat to gently rolling. End moraines are ridge-like features, 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. Three end moraines pass through Hardin County. The Fort Wayne Moraine runs nearly east/west across the northern edge of the county. The Wabash Moraine crosses the county in a somewhat northwest/southeast direction from the vicinity of Alger, through Kenton, and into Marion County just north of the Scioto River. The St. Johns Moraine roughly parallels the Wabash Moraine through the county from the border between Marion and Roundhead townships to the southeastern corner of the county.

Alluvial deposits (alluvium) are sediments laid down by streams and rivers on either a floodplain or within their main channel. Alluvium will vary in nature from fine sand to silty-sand to clayey silt. In Hardin County, coarser alluvium is more common in the larger streams and finer alluvium is more common in the smaller tributaries or headwaters of streams.

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. Typically, these deposits may collapse or flow as the surrounding ice melts. They 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, while eskers are comprised of elongate, narrow, sinuous ridges of sand and gravel. These ice contact deposits are found in small, isolated areas in central and southwestern in Hardin County. The largest concentration of these types of deposits is found in the southwest corner of the county, just south of the Village of Roundhead (Pavey et al., 1999).

Lacustrine deposits are composed of silty to clayey material deposited at the bottoms of lakes. Lacustrine deposits also 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.

The lakes that existed in Hardin County were intermorainal lakes; that is, they occupied low areas of ground moraine between end moraines. The thin, surficial deposits from these intermorainal lakes are found in low-lying areas in the northern and western portion of the county. These lakes were created during the recession of the ice sheets. Meltwater was trapped between the receding ice sheet and end moraines, forming a lake. Additional ponding may have resulted from northerly-flowing, run-off-fed streams that were blocked by the ice sheets. Eventually, some of these ponds may have overflowed their margins and began to cut an outlet. 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 diminished over time. Recently, many such remaining features were drained to make the land suitable for agricultural use.

Outwash deposits are created by active deposition of sediments by meltwater streams (streams resulting from melting glacial ice). These deposits are generally bedded or stratified and are sorted. Outwash deposits in Hardin County are found in the buried valley in the western part of the county and along parts of the southern margin of the Wabash Moraine.

The sorting and degree of coarseness of outwash deposits depend upon the nature and proximity of the melting ice sheet. Braided streams are the usual vehicle for depositing 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 retreating ice sheet.

Bedrock Geology

Bedrock underlying the surface of Hardin County belongs to the Silurian System. Carbonate (limestone and dolomite) rocks underlie the entire county. Table 9 summarizes the bedrock stratigraphy found in Hardin 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.

The youngest bedrock unit in Hardin County is the Undifferentiated Salina Dolomite. These rocks consist of clay-rich dolomites, fine-grained limestones, and thin evaporate deposits such as gypsum. Undifferentiated Salina rocks are found in the northwest and south-central parts of the county. Ground water yields may exceed 100 gallons per minute in the northwest corner of the county where these rocks are the thickest.

The Tymochtee and Greenfield rocks are found throughout most of the county, except in deep bedrock valleys where they have been eroded away. These formations occur either directly below the glacial deposits that mantle the county or underlying the Undifferentiated Salina Dolomite. The highest yields from these bedrock aquifers are generally in the western portion of the county.

The Lockport Dolomite is the oldest bedrock unit present and the last formation capable of producing potable water in this area. It underlies the Tymochtee and Greenfield everywhere those units are found in the county and also underlies the glacial deposits in the deeply eroded bedrock valleys. Thickness exceeds 100 feet throughout the county and ground water yields are typically greater than 100 gallons per minute to properly designed, large diameter wells.

Ground Water Resources

Ground water for most domestic, industrial, agricultural, and public water supplies is obtained from the carbonate bedrock aquifers. A few wells, primarily domestic, obtain supplies from isolated sand and gravel lenses and layers within the ground moraine or end moraine deposits. Somewhat thicker and more extensive sand and gravel deposits occur within the buried valley in the western part of the county.

Yields of 25 to over 500 gallons per minute (gpm) are possible from properly designed, large diameter wells penetrating deep into the carbonate aquifer. Typical yields from the occasional sand and gravel units within the ground and end moraines are 5 to 25 gpm. Yields in excess of 100 gpm are possible from properly designed large diameter wells completed in some portions of the buried valley.

Table 9. Bedrock stratigraphy of Hardin County

System	Group/Formation (Symbol)	Lithologic Description
Silurian	Undifferentiated Salina Dolomite (Sus)	Gray to brown, thin-bedded, argillaceous dolomite. Thin evaporite zones common. This unit exists only in western and southern parts of the county. Yields may exceed 100 gpm when fractures or solution features are encountered. Thickness does not exceed 100 ft. anywhere in the county.
	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 increases along margins of contact with the Sus, as does the yield to wells, which may exceed 100 gpm in this area. Typical yields can range from 0 to 100 gpm.
	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. Is in the subsurface throughout the county, and is the uppermost unit in the buried valley that runs from the southwest corner to the center of the county.

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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 3527 water well log records are on file for Hardin County. Data from roughly 1618 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 Hardin County* (Schmidt, 1982) provided generalized depth to water information throughout 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 Logan County (Sprowls, 1995), Allen County (Angle and Barrett, 2005), Marion County (Angle, 2003), Union County (Angle, 2004), Wyandot County (Angle and Barrett, 2005), Auglaize County (Angle and Barrett, 2005), and Hancock County (Smith, 1994) were used as a guideline. Topographic and geomorphic trends were utilized in areas where other sources of data were lacking.

Depths of 0 to 5 feet (10) were assigned to a limited area within the 7D-Buried Valley setting in the southwestern corner of the county. Depths of 5 to 15 feet (9) were selected for all of the 7Ec-Alluvium over Sedimentary Rock settings and many of the 7D-Buried Valley and 7Fc-Intermorainal Lake Deposits settings. Depths to water of 15 to 30 feet (7) were used for most of the portions of the county covered with ground moraine and associated with the 7Ac-Glacial Till over Limestone setting. The setting 7Af-Sand and Gravel interbedded in Glacial Till is found primarily along the boundary with Hancock County; in most cases this setting has a depth of 15 to 30 feet (7). Depths to water of 15 to 30 feet were also utilized for the majority of the 7C-Moraine setting (especially along the flanks of the moraines) and 7J-Glacial Complex settings. Depths to water of 30 to 50 feet (5) are found in some of the areas with 7Ac-Glacial Till over Limestone and 7C-Moraine. Depths to water of 50 to 75 feet (3) were utilized for some higher elevation crests of the end moraines and for a few areas of 7J-Glacial Complex and 7Ac-Glacial Till over Limestone with thicker than average drift.

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) and Dumouchelle and Schiefer (2002) proved to be helpful. Recharge ratings from neighboring Logan County (Sprowls, 1995), Allen County (Angle and Barrett, 2005), Marion County (Angle, 2003), Union County (Angle, 2004), Wyandot County (Angle and Barrett, 2005), Auglaize County (Angle and Barrett, 2005), and Hancock County (Smith, 1994) were used as a guideline.

Values of 7 to 10 inches per year (8) were used for areas of high recharge. These values were found primarily within the 7Ec-Alluvium over Sedimentary Rock setting. Values of 4 to 7 inches per year (6) were selected for areas with moderate recharge. This range of recharge values was selected for the majority of settings and areas in Hardin County. Values of 2 to 4 inches per year (3) were selected for areas with low recharge. These values were assigned to the 7Fc-Intermorainal Lake Deposits setting.

Aquifer Media

Information on evaluating aquifer media was obtained from the *Ground Water Resources of Hardin County* (Schmidt, 1982). 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 Logan County (Sprowls, 1995), Allen County (Angle and Barrett, 2005), Marion County (Angle, 2003), Union County (Angle, 2004), Wyandot County (Angle and Barrett, 2005), Auglaize County (Angle and Barrett, 2005), and Hancock County (Smith, 1994) were used 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 much 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 and a similar report (Norris and Fidler, 1973) on carbonate rocks in southwestern Ohio. Well log records on file at the ODNR, Division of Water, were an important source of aquifer information.

All of the bedrock, except where the overlying deposits are thin, 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). The Silurian Limestone and Dolomite bedrock is the predominant aquifer underlying the county. A rating of (8) was assigned to these units along the far western margin of the county due to some increased solution and jointing at depth in the Silurian Lockport Dolomite in adjoining Mercer County. A rating of (7) was applied to all of the remaining Silurian limestone and dolomite aquifers in Auglaize County.

Sand and gravel is the aquifer in a broad band across west-central and southwestern Auglaize County consisting of buried valley, end moraine and glacial complex deposits. The 7D-Buried Valley setting is associated with pre-glacial drainage systems. The sand and gravel aquifers in this setting and the immediately adjacent 7C-End Moraine and 7J-Glacial Complex settings were assigned an aquifer rating of (7). A sand and gravel aquifer rating of (7) was more widely applied for the St. Johns Moraine than the other end moraines. Sand and gravel was also the aquifer for the 7Af-Sand and Gravel Interbedded in Glacial Till, and the 7Ed-Alluvium over Glacial Till settings with a rating of (6). Sand and gravel aquifers associated with 7C-End Moraine and 7J-Glacial Complex settings located away from the 7D-Buried Valley settings were given a rating of (6), as the sand and gravel lenses tended to thin and become finer-grained further from the buried valleys. Yields and drawdown data reported on water well log records were used to help evaluate the sand and gravel deposits.

The delineation of buried valleys, end moraines, and glacial complexes are based primarily on the Division of Water's state aquifer map (ODNR, Division of Water, Glacial State Aquifer Map, 2000)

Soils

Soils were mapped using the data obtained from the *Soil Survey of Hardin County* (Miller and Robbins, 1987), as well as data from the United States Department of Agriculture Natural Resource Conservation Service's Soil Data Mart (2007). 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 Hardin 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 Hardin County.

Peat (8) occurs in some minor depressions and kettles associated with the 7D-Buried Valley setting. Shrink-swell (non-aggregated) clays (7) are associated with some of the highly clayey soils found at the surface of some of the 7Fc-Intermorainal Lake Deposits settings. Sandy loam (6) soils develop on sandy sediments associated with thin outwash mantling alluvial terraces, coarse alluvium, and areas of kames and eskers. Loam (5) soils are found at a number of areas where the surficial deposits had an intermediate texture soil. These areas commonly consist of thin layers of fine sand overlying finer-grained materials. This includes mostly areas of thin outwash or coarse alluvium overlying either finer alluvium or till along the margins of major streams. Silt loam (4) typically occurs with silty, finer-grained alluvial and floodplain deposits. Clay loam (3) soils were evaluated for the majority of the county including till overlying ground moraine and end moraine areas. Clay loam (3) was also selected for some fine-grained alluvial deposits.

Topography

Topography, or percent slope, was evaluated using U.S.G.S. 7-1/2 minute quadrangle maps and the *Soil Survey of Hardin County* (Miller and Robbins, 1987). Slopes of 0 to 2 percent (10) occur with 7Fc-Intermorainal Lake Deposits setting, alluvial and floodplain deposits, and flatter-lying portions of ground moraine. Slopes of 2 to 6 percent (9) were selected for most areas of both slightly rolling ground moraine and end moraines. Slopes of 6 to 12 percent (5) are found in limited number of areas along the margins of end moraines where down-cutting streams had more steeply dissected the topography.

Table 10. Hardin County soils

Soil Name	Parent Material/ Setting	DRASTIC Rating	Soil Media
Belmore	Outwash, kame	6	Sandy loam
Blount	Till	3	Clay loam
Carlisle	Kettle bogs	8	Peat
Colwood	Glacial lake	5	Loam
Del Rey	Glacial lake	3	Clay loam
Eel	Alluvium	6	Sandy loam
Flatrock	Loamy alluvium	4	Silt loam
Fox	Outwash	6	Sandy loam
Fulton	Glacial lake	7	Shrink-swell clay
Genesee	Alluvium	4	Silt loam
Glynwood	Till	3	Clay loam
Haskins	Glacial lake over till	3	Clay loam
Houcktown	Till	3	Clay loam
Kendallville	Loess over outwash over till	3	Clay loam
Kibbie	Outwash, kame	6	Sandy Loam
Knoxdale	Loamy alluvium	5	Loam
Latty	Glacial lake	7	Shrink-swell clay
Linwood	Bog	8	Peat
Martinsville	Outwash	6	Sandy Loam
McGuffey	Lacustrine	7	Shrink-swell clay
Milford	Silty lacustrine	3	Clay loam
Millsdale	Thin to limestone	10	Thin to absent
Milton	Thin to limestone	10	Thin or absent
Montgomery	Clayey lacustrine, oxbows	7	Shrink-swell clay
Morley	Clayey and loamy till	3	Clay loam
Nappanee	Wave-planed till	3	Clay loam
Newark	Alluvium	4	Silt loam
Nolin	Alluvium	4	Silt loam
Ockley	Outwash, kame along moraines	6	Sandy loam
Olentangy	Depressions, lacustrine	2	Muck
Patton	Depressions, lacustrine	3	Clay loam
Pewamo	Till in low areas, depressions	3	Clay loam
Roundhead	Silty lacustrine	4	Silt loam
Saranac	Alluvium, slackwater	3	Clay loam
Shoals	Alluvium	4	Silt loam
Shinrock	Lacustrine, fine deltaic	4	Silt loam
Sleeth	Outwash, coarse alluvium	6	Sandy loam
Sloan	Alluvium , floodplain	4	Silt loam
Walkill	Kettle, depression	8	Peat
Westland	Outwash, kame	4	Silt Loam

Impact of the Vadose Zone Media

Information on evaluating vadose zone media was obtained in part from the *Ground Water Resources of Hardin County* (Schmidt, 1982) 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 neighboring Logan County (Sprowls, 1995), Allen County (Angle and Barrett, 2005), Marion County (Angle, 2003), Union County (Angle, 2004), Wyandot County (Angle and Barrett, 2005), Auglaize County (Angle and Barrett, 2005), and Hancock County (Smith, 1994) were used as a guideline. 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 Auglaize County* (Cunningham and Priest, 1981) 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 Hardin 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/fractured till with a vadose zone media rating of (6) was selected for parts of Hardin County where the till covering the underlying limestone was thin, averaging from roughly 5 to 25 ft. This vadose zone media is only found within the 7Ac-Glacial Till over Limestone setting.

Glacial till was given vadose zone media ratings of (5) or (4). A rating of (5) was applied to most areas with a thin to moderate thickness (generally less than 75 feet) of till. A vadose zone media rating of (4) was used for most areas with thick till (generally greater than 75 feet). Ratings of (4) were most common in the 7Ac-Glacial Till over Limestone and 7J-Glacial Complex settings.

Sand and gravel with a vadose zone media rating of (6) was assigned to isolated areas within the 7Ba-Outwash setting due to the relative coarseness of the deposits and lack of fine material. The vadose media selected for the remainder of the outwash settings was sand and gravel with significant silt and clay (6). This media was also chosen for many of the 7D-Buried Valley settings.

Silt and clay with a rating of (5) or (4) was applied to fine-grained alluvium associated many minor tributary streams and the headwaters of streams. Silt and clay with a vadose zone rating of (3) was used for the majority of the 7Fc-Intermorainal Lake Deposits settings due to the very fine-grained, lacustrine nature of the deposits.

Hydraulic Conductivity

Information on evaluating the hydraulic conductivity was obtained primarily from the following maps and reports: ODNR, Div. of Water, (1970), Norris and Fidler (1973), and the *Ground Water Resources of Hardin County* (Schmidt, 1982). 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 Logan County (Sprowls, 1995), Allen County (Angle and Barrett, 2005), Marion County (Angle, 2003), Union County (Angle, 2004), Wyandot County (Angle and Barrett, 2005), Auglaize County (Angle and Barrett, 2005), and Hancock County (Smith, 1994) were used as a guideline. The ODNR, Division of Water, Glacial State Aquifer Map (2000) and Bedrock State Aquifer Map (2000) were important sources of hydraulic conductivity data. 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 generally correspond to aquifer ratings; i.e., the more highly rated aquifers have higher values for hydraulic conductivity. Some sand and gravel aquifers associated with the 7D-Buried Valley setting and all sand and gravel aquifers associated with the 7Ba-Outwash 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 thicker and coarser sand and gravel layers found in these settings. All remaining sand and gravel aquifers were assigned a hydraulic conductivity range of 300-700 gpd/ft^2 (4).

Limestone aquifers along the southern border with Logan County were given a hydraulic conductivity range of 700-1,000 gpd/ft^2. This was due to the high amount solution features encountered in Logan County. All remaining limestone aquifers were assigned a hydraulic conductivity range of 300-700 gpd/ft^2 (4).

APPENDIX B

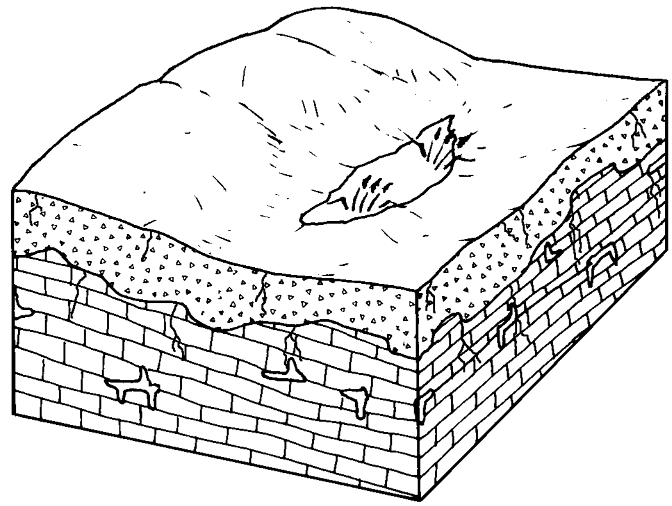
DESCRIPTION OF HYDROGEOLOGIC SETTINGS AND CHARTS

Ground water pollution potential mapping in Hardin County resulted in the identification of eight hydrogeologic settings within the Glaciated Central Region. The list of these settings, the range of pollution potential index calculations, and the number of index calculations for each setting are provided in Table 11. Pollution potential indexes for Hardin County range from 99 to 168.

Table 11. Hydrogeologic settings mapped in Hardin County, Ohio

Hydrogeologic Settings	Range of GWPP Indexes	Number of Index Calculations
7 Ac-Glacial till over limestone	112-162	37
7 Af-Sand and gravel interbedded in glacial till	129-148	7
7 Ba-Outwash	144-168	7
7 C-Moraine	100-145	19
7 D-Buried valley	129-168	29
7 Ec-Alluvium over sedimentary rock	130-167	13
7 Fc-Intermorainal lake deposits	99-139	12
7 J-Glacial complex	128-138	7

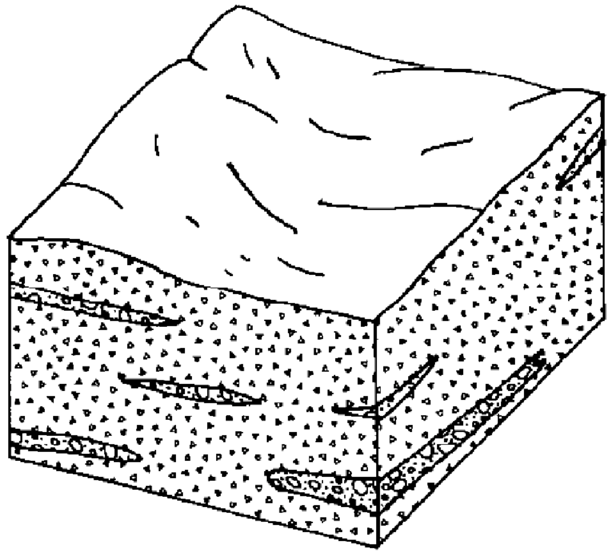
The following information provides a description of each hydrogeologic setting identified in the county, a block diagram illustrating the characteristics of the setting, and a listing of the charts for each unique combination of pollution potential indexes calculated for each setting. The charts provide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



<u>7Ac-Glacial Till over Limestone</u>

This hydrogeologic setting is common across Hardin County. Areas with this hydrologic setting are characterized by flat-lying topography and 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 thin and weathered. Where the till is thin (less than 25 feet), fractured limestone along with the till is considered to be the vadose zone media. The aquifer is composed of fractured Silurian 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 typically are clay loams derived from till. Maximum ground water yields greater than 500 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.

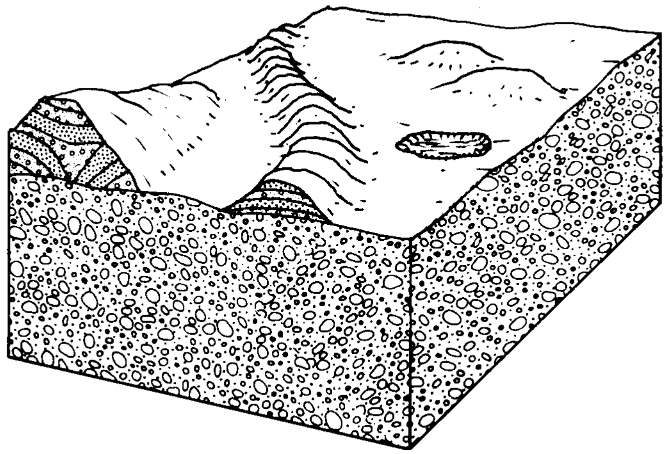
GWPP index values for the hydrogeologic setting of Glacial Till over Limestone range from 112 to 162, with the total number of GWPP index calculations equaling 37.



7Af-Sand and Gravel Interbedded in Glacial Till

This hydrogeologic setting is scattered throughout Hardin County. The area is characterized by flat lying topography and low relief. The setting is commonly associated with areas of ground moraine. The setting also features a moderate thickness of glacial drift, as opposed to the thicker drift encountered in the 7C-Moraine, 7D-Buried Valley, and 7J-Glacial Complex settings. The vadose zone is typically composed of silty to clayey glacial till, though in selected areas along the northern border with Hancock County it consists of sand and gravel with silt and clay. The till may be fractured or jointed, particularly in areas where it is predominantly thin and weathered. Depth to water is usually shallow, averaging 30 feet or less. Soils are primarily 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.

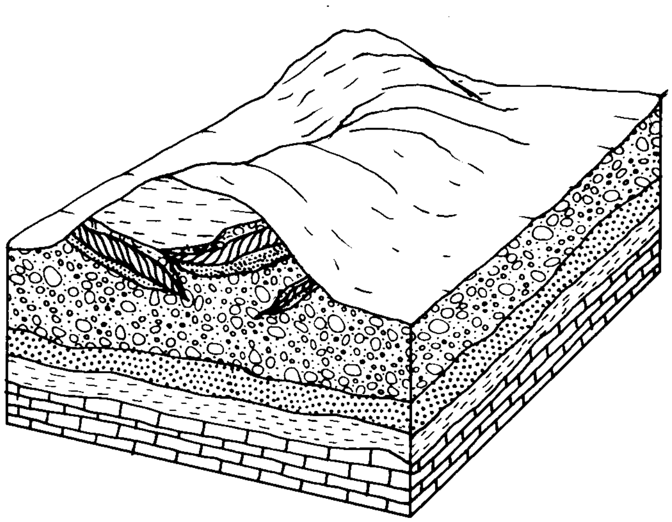
GWPP index values for the hydrogeologic setting of Sand and Gravel Interbedded in Glacial Till range from 129 to 148, with the total number of GWPP index calculations equaling 7.



7Ba Outwash

This hydrogeologic setting consists of areas of outwash terraces flanking the buried valley in the southwest corner of the county, and areas along the Scioto River in the eastern part of the county. This setting is characterized by flat-lying topography and low relief. The aquifer consists of relatively thick and continuous sand and gravel outwash deposits. These sand and gravel deposits tend to be shallower than in the neighboring 7D-Buried Valley and 7C-Moraine settings. Maximum yields range up to 500 gpm for properly constructed, large diameter wells. Test drilling may be necessary to locate higher-yielding areas. Vadose zone media consists of sand and gravel, or sand and gravel mixed with silt and clay. Depth to water is commonly shallow to moderate. Soils are usually sandy loams. Recharge is moderate to high due to the relatively flat topography, relatively permeable soils and vadose media, and the shallow depth to water.

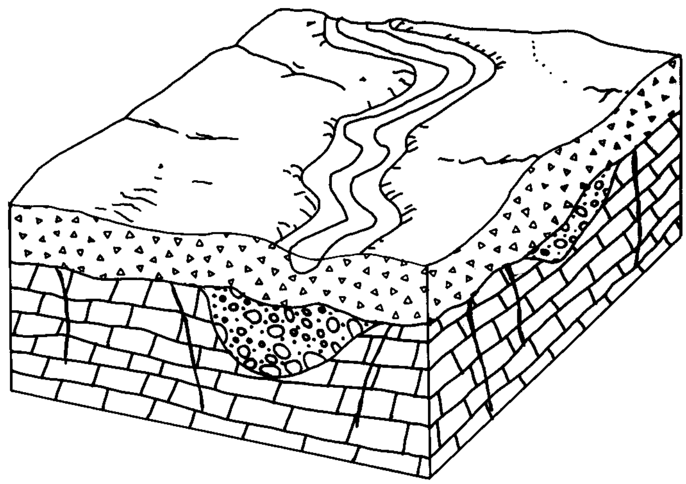
GWPP index values for the hydrogeologic setting of Outwash range from 144 to 168 with the total number of GWPP index calculations equaling 7.



<u>7C-Moraine</u>

This hydrogeologic setting consists of elongated, broad belts of end moraines that cross Hardin 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. Some crests of the moraines may also become steeper and more hummocky. The aquifer consists of sand and gravel lenses interbedded with the fine-grained glacial till. In areas of the moraine where water-bearing sand and gravel lenses are not encountered, the wells are completed in the underlying Silurian limestone and dolomite bedrock. Average yields for the sand and gravel lenses range 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 predominantly composed of silty to clayey glacial till; however, in selected areas along the northern border with Hancock County, the vadose zone consists of sand and gravel with silt and clay. Depth to water is variable and depends primarily upon the depth of the underlying aquifer and the thickness of the till. Depths to water increase along the central axis or ridge of the end moraines. Soils are commonly clay loams. Recharge is moderate. The end moraines are the primary local sources of recharge.

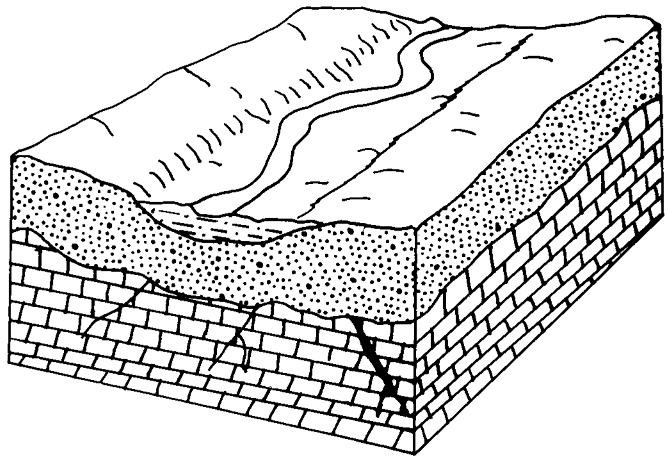
GWPP index values for the hydrogeologic setting of Moraine range from 100 to 145, with the total number of GWPP index calculations equaling 19.



<u>7D-Buried Valley</u>

This hydrogeologic setting consists of a narrow band that runs from the southwest corner of Hardin County north to an area around McGuffey, then heads east toward Kenton, where it stops just west of the city. 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 overly these deposits. The setting is characterized by a thick sequence of glacial till. The aquifer consists of thinner, less continuous lenses of sand and gravel interbedded with thicker sequences of fine-grained glacial till. Thin layers of alluvial or lacustrine silt, clay, or fine sand may also be present at greater depths. Yields from relatively thin sand and gravel lenses are commonly less than 25 gpm, though thicker lenses with cleaner sand and gravel may yield more. Soils are usually clayey, silty, or sandy loams derived from the overlying glacial till. In a few locations, peat is the primary soil type. Depths to water range from very shallow to moderate and are dependent upon the depth to the aquifer and the overall thickness of the till. 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.

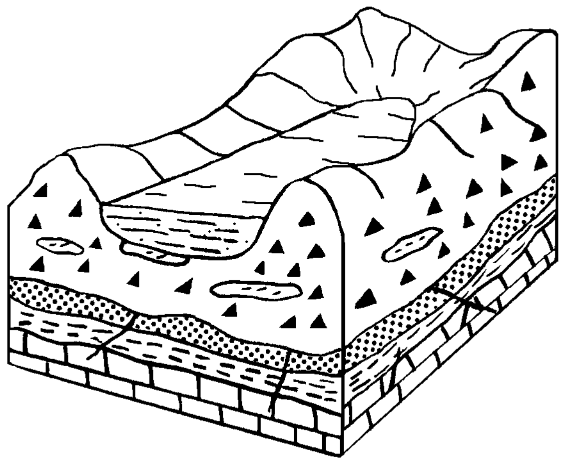
GWPP index values for the hydrogeologic setting of Buried Valley range from 129 to 168, with the total number of GWPP index calculations equaling 29.



7Ec-Alluvium over Sedimentary Rock

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 consist of Silurian limestones and dolomites. The vadose zone primarily consists of sandy to silty to clayey alluvial deposits. Soils are variable due to the varying texture of the alluvial materials and are typically sandy, silty, or clay loams. Depth to water is 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 in between. Maximum ground water yields greater than 100 gpm are possible from the Silurian Lockport, Tymochtee, Greenfield and Salina Groups. Recharge is moderate to 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.

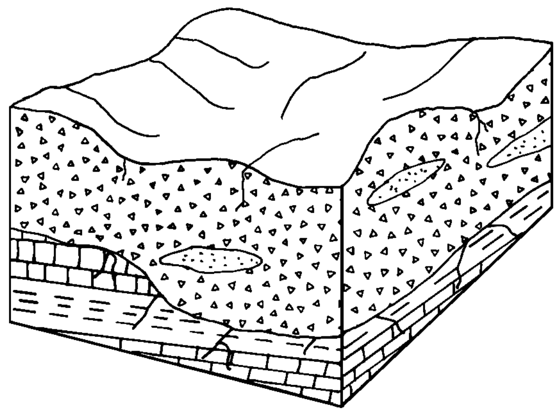
The GWPP index values for the hydrogeologic setting Alluvium over Sedimentary Rocks range from 130 to 167, with the total number of GWPP index calculations equaling 13.



<u>7Fc-Intermoranial Lake Deposits</u>

This hydrogeologic setting is characterized by flat-lying topography and 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 low-lying areas across Hardin County. The vadose zone media consists of silty to clayey lacustrine sediments. The aquifer consists of the underlying Silurian limestones 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 deep. Soils are fine clay loams or shrink-swell (aggregated) clays derived from clayey lacustrine sediments. Recharge in this setting is low to moderate due to the relatively low permeability soils and vadose.

GWPP index values for the hydrogeologic setting of Intermorainal Lake Deposits range from 99 to 139, with the total number of GWPP index calculations equaling 12.



7J-Glacial Complex

This setting is primarily found in central Hardin County along the Wabash moraine. The surface topography is flat and has low relief. Modern streams typically do not overly these deposits. The aquifer consists of thinner, less continuous lenses of sand and gravel interbedded with thicker sequences of fine-grained glacial till. Yields from wells completed in the sand and gravel lenses average from 5 to 25 gpm. Wells that do not encounter sand and gravel deposits capable of yielding sufficient water for household use are completed in the limestone bedrock. Maximum ground water yields greater than 100 gpm are possible from the Silurian Lockport, Tymochtee, Greenfield and Salina Groups. The setting is similar to the 7D-Buried Valley except that the sand and gravel lenses are less common, less continuous in lateral extent, and the overall thickness of drift is somewhat less. Soils are clay loams derived from the overlying glacial till. Depths to water are shallow to moderate and depend upon the depth of the aquifer and the thickness of the till. Recharge is moderate due to the fine-grained nature of the soils and vadose zone media and the moderate depth to the limestone or sand and gravel aquifers.

GWPP index values for the hydrogeologic setting of Glacial Complex range from 128to 138, with the total number of GWPP index calculations equaling 7.

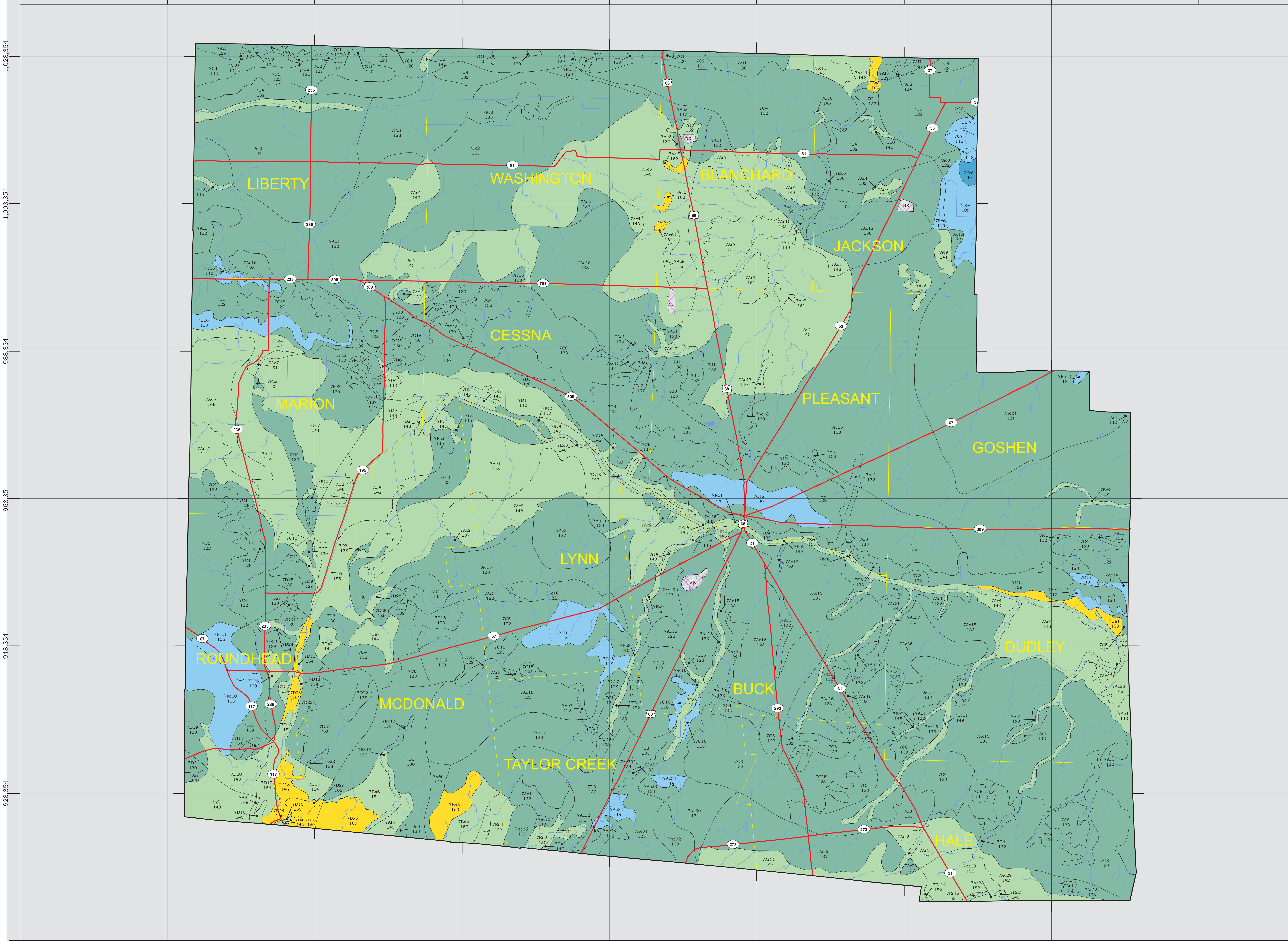
Table 12. Hydrogeologic Settings, DRASTIC Factors, and Ratings

Setting	Depth to Water	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pesticide Rating
7Ac1	15-30	4-7	limestone	Clay Loam	2-6	till	300-700	132	150
7Ac2	15-30	4-7	limestone	Clay Loam	2-6	limestone fractured till	300-700	137	154
7Ac3	30-50	4-7	limestone	Clay Loam	2-6	till	300-700	122	140
7Ac4	5-15	4-7	limestone	Clay Loam	0-2	till	300-700	143	163
7Ac5	5-15	4-7	limestone	Clay Loam	0-2	limestone fractured till	300-700	148	167
7Ac6	5-15	4-7	limestone	Thin or Absent Gravel	0-2	limestone	300-700	162	202
7Ac7	5-15	4-7	limestone	Shrink/swell clay	0-2	till	300-700	151	183
7Ac8	15-30	4-7	limestone	Thin or Absent Gravel	0-2	limestone	300-700	152	192
7Ac9	15-30	4-7	limestone	Shrink/swell clay	0-2	till	300-700	141	173
7Ac10	15-30	4-7	limestone	Silty Loam	0-2	till	300-700	135	158
7Ac11	15-30	4-7	limestone	Clay Loam	2-6	sand & gravel w/silt & clay	300-700	142	158
7Ac12	15-30	4-7	limestone	Clay Loam	0-2	limestone fractured till	300-700	138	157
7Ac13	15-30	4-7	limestone	Clay Loam	0-2	sand & gravel w/silt & clay	300-700	143	161
7Ac14	50-75	4-7	limestone	Clay Loam	2-6	till	300-700	112	130
7Ac15	15-30	4-7	limestone	Clay Loam	0-2	till	300-700	133	153
7Ac16	30-50	4-7	limestone	Clay Loam	0-2	till	300-700	123	143
7Ac17	5-15	4-7	limestone	Sandy Loam	0-2	till	300-700	149	178
7Ac18	15-30	4-7	limestone	Sandy Loam	0-2	till	300-700	139	168
7Ac19	30-50	4-7	limestone	Sandy Loam	0-2	till	300-700	129	158
7Ac20	30-50	4-7	limestone	Silty Loam	0-2	till	300-700	125	148
7Ac21	15-30	2-4	limestone	Clay Loam	0-2	till	300-700	121	141
7Ac22	5-15	4-7	limestone	Clay Loam	2-6	till	300-700	142	160
7Ac23	5-15	4-7	limestone	Clay Loam	6-12	till	300-700	139	151
7Ac24	15-30	4-7	limestone	Clay Loam	0-2	till	300-700	136	156
7Ac25	5-15	4-7	limestone	Clay Loam	0-2	till	700-1000	147	166
7Ac26	15-30	4-7	limestone	Clay Loam	0-2	till	700-1000	137	156
7Ac27	5-15	4-7	limestone	Clay Loam	2-6	till	700-1000	146	163
7Ac28	5-15	4-7	limestone	Clay Loam	0-2	till	700-1000	152	170
7Ac29	15-30	4-7	limestone	Clay Loam	0-2	till	700-1000	142	160
7Ac30	15-30	4-7	limestone	Clay Loam	0-2	till	700-1000	134	153
7Ac31	30-50	4-7	limestone	Clay Loam	2-6	till	700-1000	123	140
7Ac32	15-30	4-7	limestone	Clay Loam	2-6	till	700-1000	133	150
7Ac33	30-50	4-7	limestone	Clay Loam	0-2	till	700-1000	124	143
7Ac34	30-50	4-7	limestone	Clay Loam	6-12	till	700-1000	119	128
7Ac35	50-75	4-7	limestone	Sandy Loam	0-2	sand & gravel w/silt & clay	700-1000	130	156
7Ac36	15-30	4-7	Limestone	Clay loam	0-2	Till	300-700	134	153
7Ac37	15-30	4-7	Limestone	Clay loam	2-6	Till	300-700	133	150
7Af1	15-30	4-7	sand & gravel	Clay Loam	0-2	sand & gravel w/silt & clay	300-700	130	150

Setting	Depth to Water	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pesticide Rating
7Af2	15-30	4-7	sand & gravel	Loam	0-2	sand & gravel w/silt & clay	300-700	134	160
7Af3	15-30	4-7	sand & gravel	Clay Loam	2-6	sand & gravel w/silt & clay	300-700	129	147
7Af4	15-30	4-7	sand & gravel	Clay Loam	0-2	till	300-700	133	153
7Af5	5-15	4-7	sand & gravel	Clay Loam	0-2	till	300-700	143	163
7Af6	0-5	4-7	sand & gravel	Clay Loam	0-2	till	300-700	148	168
7Af7	15-30	4-7	sand & gravel	Clay Loam	0-2	till	300-700	130	150
7Ba1	5-15	7-10	sand & gravel	Sandy Loam	0-2	sand & gravel w/silt & clay	700-1000	168	194
7Ba2	15-30	4-7	sand & gravel	Sandy Loam	0-2	sand & gravel	700-1000	150	176
7Ba3	15-30	4-7	sand & gravel	Shrink/swell clay	6-12	sand & gravel w/silt & clay	700-1000	147	166
7Ba4	15-30	4-7	sand & gravel	Sandy Loam	0-2	sand & gravel	700-1000	147	173
7Ba5	5-15	4-7	sand & gravel	Sandy Loam	0-2	sand & gravel w/silt & clay	700-1000	160	186
7Ba6	5-15	4-7	sand & gravel	Clay Loam	0-2	sand & gravel w/silt & clay	700-1000	154	171
7Ba7	15-30	4-7	sand & gravel	Clay Loam	0-2	sand & gravel w/silt & clay	700-1000	144	161
7C1	15-30	4-7	sand & gravel	Clay Loam	2-6	sand & gravel w/silt & clay	100-300	120	140
7C2	15-30	4-7	sand & gravel	Clay Loam	0-2	sand & gravel w/silt & clay	100-300	121	143
7C3	15-30	7-10	sand & gravel	Sand	2-6	sand & gravel w/silt & clay	100-300	145	182
7C4	15-30	4-7	limestone	Clay Loam	2-6	till	300-700	132	150
7C5	30-50	4-7	limestone	Clay Loam	2-6	till	300-700	122	140
7C6	50-75	4-7	limestone	Clay Loam	0-2	till	300-700	113	133
7C7	50-75	4-7	limestone	Clay Loam	2-6	till	300-700	112	130
7C8	15-30	4-7	limestone	Clay Loam	0-2	till	300-700	133	153
7C9	15-30	4-7	limestone	Shrink/swell clay	0-2	till	300-700	141	173
7C10	15-30	4-7	limestone	Sand	0-2	till	300-700	145	183
7C11	15-30	4-7	limestone	Clay Loam	6-12	till	300-700	128	138
7C12	50-75	2-4	limestone	Clay Loam	2-6	till	300-700	100	118
7C13	5-15	4-7	limestone	Clay Loam	0-2	till	300-700	143	163
7C14	5-15	4-7	limestone	Clay Loam	2-6	till	300-700	142	160
7C15	30-50	4-7	limestone	Clay Loam	0-2	till	300-700	123	143
7C16	30-50	4-7	limestone	Clay Loam	6-12	till	300-700	118	128
7C17	15-30	4-7	limestone	Clay Loam	6-12	till	300-700	128	138
7C18	15-30	4-7	sand & gravel	Clay Loam	2-6	till	300-700	129	147
7C19	15-30	4-7	sand & gravel	Clay Loam	0-2	till	300-700	130	150
7D1	5-15	4-7	sand & gravel	Clay Loam	0-2	till	300-700	140	160
7D2	5-15	4-7	sand & gravel	Shrink/swell clay	0-2	till	300-700	148	180

Setting	Depth to Water	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pesticide Rating
7D3	15-30	4-7	sand & gravel	Clay Loam	0-2	till	300-700	130	150
7D4	5-15	4-7	sand & gravel	Silty Loam	0-2	till	300-700	142	165
7D5	5-15	4-7	sand & gravel	Loam	0-2	till	300-700	144	170
7D6	5-15	4-7	sand & gravel	Sandy Loam	0-2	till	300-700	146	175
7D7	5-15	4-7	sand & gravel	Clay Loam	2-6	till	300-700	139	157
7D8	5-15	4-7	sand & gravel	Muck	0-2	till	300-700	138	155
7D9	15-30	4-7	sand & gravel	Clay Loam	2-6	till	300-700	129	147
7D10	5-15	4-7	sand & gravel	Peat	0-2	sand & gravel w/silt & clay	300-700	155	189
7D11	15-30	4-7	sand & gravel	Sand	0-2	till	300-700	142	180
7D12	15-30	4-7	sand & gravel	Sandy Loam	0-2	till	300-700	136	165
7D13	5-15	4-7	sand & gravel	Clay Loam	0-2	sand & gravel w/silt & clay	700-1000	154	171
7D14	0-5	4-7	sand & gravel	Sandy Loam	0-2	till	700-1000	160	187
7D15	0-5	4-7	sand & gravel	Peat	0-2	sand & gravel w/silt & clay	300-700	155	190
7D16	0-5	4-7	sand & gravel	Clay Loam	0-2	till	300-700	145	165
7D17	0-5	4-7	sand & gravel	Clay Loam	0-2	till	700-1000	154	172
7D18	5-15	4-7	sand & gravel	Sandy Loam	0-2	sand & gravel w/silt & clay	700-1000	160	186
7D19	15-30	4-7	sand & gravel	Clay Loam	0-2	sand & gravel w/silt & clay	300-700	133	153
7D20	5-15	4-7	sand & gravel	Clay Loam	0-2	till	300-700	143	163
7D21	15-30	4-7	sand & gravel	Clay Loam	0-2	till	700-1000	139	157
7D22	15-30	4-7	sand & gravel	Clay Loam	2-6	till	700-1000	138	154
7D23	5-15	4-7	sand & gravel	Peat	0-2	sand & gravel w/silt & clay	700-1000	164	196
7D24	15-30	4-7	sand & gravel	Peat	0-2	sand & gravel w/silt & clay	700-1000	154	186
7D25	15-30	4-7	sand & gravel	Clay Loam	0-2	till	300-700	130	150
7D26	15-30	4-7	sand & gravel	Sandy Loam	0-2	sand & gravel w/silt & clay	700-1000	150	176
7D27	15-30	4-7	sand & gravel	Peat	0-2	sand & gravel w/silt & clay	700-1000	154	186
7D28	15-30	4-7	sand & gravel	Peat	0-2	sand & gravel w/silt & clay	300-700	140	175
7D29	5-15	4-7	sand & gravel	Thin or Absent Gravel	0-2	sand & gravel w/silt & clay	700-1000	168	206
7Ec1	5-15	4-7	limestone	Silty Loam	0-2	sand & gravel w/silt & clay	300-700	145	168
7Ec2	5-15	4-7	limestone	Silty Loam	0-2	silt & clay	300-700	145	168
7Ec3	5-15	7-10	limestone	Silty Loam	0-2	sand & gravel w/silt & clay	100-300	162	184
7Ec4	5-15	7-10	limestone	Sandy Loam	0-2	sand & gravel w/silt & clay	300-700	167	194
7Ec5	5-15	4-7	limestone	Clay Loam	0-2	silt & clay	300-700	138	159
7Ec6	5-15	7-10	limestone	Sandy Loam	0-2	silt & clay	300-700	152	182
7Ec7	5-15	7-10	limestone	Silty Loam	0-2	silt & clay	300-700	148	172
7Ec8	5-15	7-10	limestone	Clay Loam	0-2	silt & clay	300-700	146	167

Setting	Depth to Water	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pesticide Rating
7Ec9	5-15	7-10	limestone	Silty Loam	0-2	silt & clay	300-700	153	176
7Ec10	5-15	7-10	limestone	Sandy Loam	0-2	silt & clay	300-700	157	186
7Ec11	5-15	4-7	limestone	Sandy Loam	0-2	silt & clay	300-700	149	178
7Ec12	5-15	4-7	limestone	Clay Loam	0-2	till	700-1000	152	170
7Ec13	5-15	4-7	sand & gravel	Clay Loam	0-2	silt & clay	300-700	130	152
7Fc1	15-30	4-7	limestone	Clay Loam	0-2	silt & clay	300-700	123	145
7Fc2	5-15	4-7	limestone	Clay Loam	0-2	silt & clay	300-700	133	155
7Fc3	5-15	4-7	limestone	Silty Loam	0-2	silt & clay	300-700	135	160
7Fc4	30-50	2-4	limestone	Shrink/swell clay	0-2	silt & clay	300-700	109	143
7Fc5	50-75	2-4	limestone	Shrink/swell clay	0-2	silt & clay	300-700	99	133
7Fc6	15-30	2-4	limestone	Shrink/swell clay	0-2	silt & clay	300-700	119	153
7Fc7	5-15	4-7	limestone	Shrink/swell clay	0-2	silt & clay	300-700	141	175
7Fc8	5-15	4-7	limestone	Sandy Loam	0-2	silt & clay	300-700	139	170
7Fc9	5-15	4-7	limestone	Loam	0-2	silt & clay	300-700	137	165
7Fc10	15-30	2-4	limestone	Clay Loam	0-2	silt & clay w/till	300-700	116	137
7Fc11	30-50	2-4	limestone	Clay Loam	0-2	till	300-700	106	127
7Fc12	15-30	2-4	limestone	Silty Loam	0-2	silt & clay	300-700	118	142
7J1	5-15	4-7	limestone	Clay Loam	0-2	till	300-700	138	159
7J2	5-15	4-7	limestone	Clay Loam	2-6	till	300-700	137	156
7J3	15-30	4-7	limestone	Clay Loam	0-2	till	300-700	128	149
7J4	15-30	4-7	limestone	Clay Loam	0-2	till	300-700	133	153
7J5	15-30	4-7	limestone	Clay Loam	2-6	till	300-700	132	150
7J6	15-30	4-7	sand & gravel	Clay Loam	2-6	till	300-700	129	147
7J7	15-30	4-7	sand & gravel	Clay Loam	0-2	till	300-700	130	150



Ground Water Pollution Potential of Hardin County

by Mike Hallfrisch,
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 form 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

Ohio Department of Natural Resources
Division of Water
Ground Water Resources Section
2045 Morse Road - Bldg. B
Columbus Ohio 43229-6605
www.dnr.state.oh.us

Cartography by Mark Steiner
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