GROUND WATER POLLUTION POTENTIAL OF SHELBY COUNTY, OHIO

BY

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ABSTRACT

A ground water pollution potential map of Shelby 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 form the basis of the system and incorporate the major hydrogeologic factors that affect and 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 Shelby County resulted in a map with symbols and colors which illustrate areas of varying ground water contamination vulnerability. Seven hydrogeologic settings were identified in Shelby County with computed ground water pollution potential indexes ranging from 83 to 189.

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 Shelby 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; about 4,000 of these wells exist in Shelby County.

The characteristics of the many aquifer systems in the state make ground water highly vulnerable to contamination. Measures to protect ground water from contamination usually cost less and create less impact on ground water users than clean-up of a polluted aquifer. Based on these concerns for protection of the resource, staff of the Division of Water conducted a review of various mapping strategies useful for identifying vulnerable aquifer areas. They placed particular emphasis on reviewing mapping systems that would assist in state and local protection and management programs. Based on these factors and the quantity and quality of available data on ground water resources, the DRASTIC mapping process (Aller et al., 1987) was selected for application in the program.

Considerable interest in the mapping program followed successful production of a demonstration county map and led to the inclusion of the program as a recommended initiative in the Ohio Ground Water Protection and Management Strategy (Ohio EPA, 1986). Based on this recommendation, the Ohio General Assembly funded the mapping program. A dedicated mapping unit has been established in the Division of Water, Water Resources Section to implement the ground water pollution potential mapping program on a county-wide basis in Ohio.

The purpose of this report and map is to aid in the protection of our ground water resources. This protection can be enhanced by understanding and implementing the results of this study which utilizes the DRASTIC system of evaluating an area's potential for ground water pollution. The mapping program identifies areas that are vulnerable to contamination and displays this information graphically on maps. The system was not designed or intended to replace site-specific investigations, but rather to be used as a planning and management tool. The map and report can be combined with other information to assist in prioritizing local resources and in making land use decisions.

APPLICATIONS OF POLLUTION POTENTIAL MAPS

The pollution potential mapping program offers a wide variety of applications in many counties. The ground water pollution potential map of Shelby 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.

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

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

SUMMARY OF THE DRASTIC MAPPING PROCESS

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

The DRASTIC mapping system allows the pollution potential of any area to be evaluated systematically using existing information. Vulnerability to contamination is a combination of hydrogeologic factors, anthropogenic influences, and sources of contamination in any given area. The DRASTIC system focuses only on those hydrogeologic factors which 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 Shelby County. Inherent within each hydrogeologic setting are the physical characteristics which affect the ground water pollution potential. These characteristics or factors identified during the development of the DRASTIC system include:

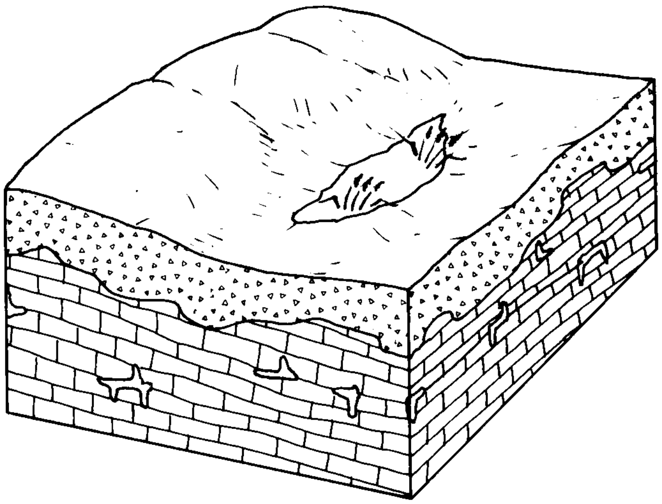
D – Depth to Water
R – Net Recharge
A – Aquifer Media
S – Soil Media
T – Topography
I – Impact of the Vadose Zone Media
C – Conductivity (Hydraulic) of the Aquifer

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.



7Ac Glacial Till Over Limestone

This hydrogeologic setting was used in central and western portions of Shelby County. The area is characterized by rolling, hummocky end moraine which overlies the limestone bedrock. The aquifer is Silurian limestones and dolomites. Ground water occurs in fractures, solution features, and vuggy zones. Yields for domestic wells typically range from 15 to 30 gpm and large diameter wells are capable of producing up to 500 gpm if major fracture systems are encountered. The overlying glacial till consists primarily of clay, silt, sand, and gravel. Sand and gravel lenses within the till are numerous but are too thin and discontinuous to constitute an aquifer. Some well drillers preferentially "by-pass" the sand and gravel lenses as it is easier to complete and develop wells in the bedrock. The thickness of the till ranges from less than 20 feet to over 100 feet in areas underlying moraines or peripheral to major buried valleys. Depth to water is highly variable and depends in part upon the thickness of the till and the proximity of surficial streams. Soils are typically clay loams. Precipitation infiltrating through the till serves as the source of recharge to the bedrock. Recharge is moderate to low and depends upon the thickness of the till, depth to water, proximity of streams, and slope.

Figure 1. Format and description of the hydrogeologic setting - 7Ac Glacial Till Over Limestone.

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

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

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

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

Weighting and Rating System

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

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

Pesticide DRASTIC

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

TABLE 1. ASSIGNED WEIGHTS FOR DRASTIC FEATURES

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

TABLE 5. RANGES AND RATINGS FOR SOIL MEDIA

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

TABLE 6. RANGES AND RATINGS FOR TOPOGRAPHY

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

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

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

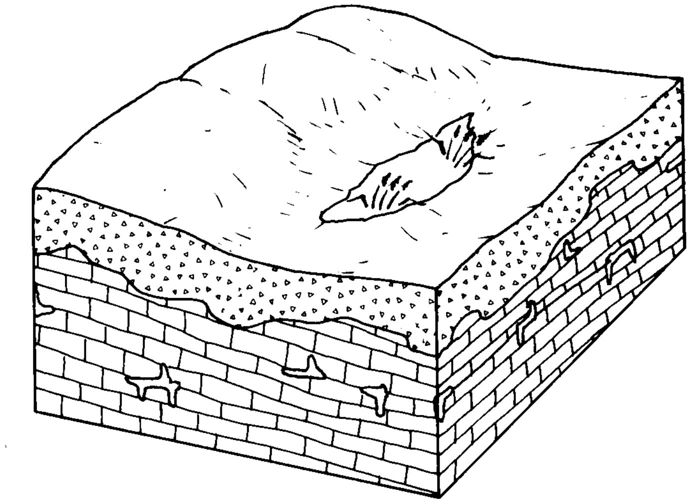
TABLE 8. RANGES AND RATINGS FOR HYDRAULIC CONDUCTIVITY

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

Integration of Hydrogeologic Settings and DRASTIC Factors

Figure 2 illustrates the hydrogeologic setting 7Ac, Glacial Till Over Solution Limestone identified in mapping Shelby 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 123. 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 Shelby County produces settings with a wide range of vulnerability to ground water contamination. Calculated pollution potential indexes for the six settings identified in the county range from 70 to 182.

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 Shelby 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 Shelby County is included with this report.



SETTING 7Ac1		GENERAL		
FEATURE	RANGE	WEIGHT	RATING	NUMBER
Depth to Water	15-75	5	3	15
Net Recharge	2-4	4	3	12
Aquifer Media	Solution Limestone	3	8	24
Soil Media	Clay Loam	2	3	6
Topography	2-6%	1	9	9
Impact of Vadose Zone	Till	5	3	15
Hydraulic Conductivity	300-700	3	4	12
		DRASTIC	INDEX	93

Figure 2. Description of the hydrogeologic setting - 7Ac Glacial Till Over Limestone

INTERPRETATION AND USE OF A GROUND WATER POLLUTION POTENTIAL MAP

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

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

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

Here the first number (7) refers to the major hydrogeologic region and the upper and lower case letters (Ac) refer to a specific hydrogeologic setting. The following number (1) references a certain set of DRASTIC parameters that are unique to this setting and are described in the corresponding setting chart. The second number (93) is the calculated pollution potential index for this unique setting. The charts for each setting provide a reference to show how the pollution potential index was derived.

The maps are color-coded using ranges depicted on the map legend. The color codes used are part of a national color-coding scheme developed to assist the user in gaining a general insight into the vulnerability of the ground water in the area. The color codes were chosen to represent the colors of the spectrum, with warm colors (red, orange, and yellow) representing areas of higher vulnerability (higher pollution potential indexes), and cool colors (greens, blues, and violet) representing areas of lower vulnerability to contamination.

The map includes information on the locations of selected observation wells. Available information on these observation wells is referenced in Appendix A, Description of the Logic in Factor Selection. Large man-made features such as landfills, quarries, or strip mines have also been marked on the map for reference.

GENERAL INFORMATION ABOUT SHELBY COUNTY

Demographics

Shelby County occupies approximately 410 square miles in west-central Ohio (Figure 3). Shelby County is bounded to the east by Logan County and Champaign County, to the north by Auglaize County, to the west by Mercer County and Darke County, and to the south by Miami County.

The approximate population of Shelby County, according to 1995 estimates, is 47,079 (Ohio Department of Development, personal communication). Sidney is the county seat and principle town. Approximately 95 percent of the land area is utilized for agriculture with the remainder devoted to urban, residential, recreational, industrial use, and woodlands. Population growth and development is primarily concentrated around Sydney and along a corridor paralleling Interstate-75. More specific information on land usage can be obtained from the ODNR, 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 51 degrees Fahrenheit for Shelby County. Harstine (1991) shows that the average temperature remains relatively constant across the county. The mean annual precipitation recorded at Sidney is 36.82 inches based upon a thirty-year (1961-1990) period (Owneby and Ezell, 1992). Harstine (1991) shows precipitation levels as being relatively constant across the county with slightly higher precipitation levels in the central portion of the county.

Figure 3. Location of Shelby County, Ohio

Physiography and Topography

Shelby County lies within the Till Plains Section of the Interior Low Plains Province (Fenneman, 1938). Frost (1931) refers to Shelby County as being within the Central Till Plains.

Shelby County is predominantly characterized by rolling, hummocky topography. This topography in large part is due to the numerous end moraines located in the county as well as the moderate amount of stream dissection. The southeastern corner of the county and the northern part of Turtle Creek Township tend to be somewhat flatter than the majority of the county. Elevations range from 1150 feet in the extreme southeast corner of the county to 870 feet just south of Lockington where the Great Miami River exits the county. Local relief is typically limited to approximately 100 to 120 feet.

Modern Drainage

The majority of Shelby County is drained by the Great Miami River and its tributaries. The Great Miami River has several short tributaries which drain much of eastern, southeastern, and south central Shelby County. Loramie Creek, which drains much of north central and western Shelby County is the primary tributary within the county. It joins the Great Miami River in Miami County, just south of the county line. The Great Miami River eventually empties into the Ohio River west of Cincinnati.

The St. Johns Moraine lies just to the northwest of Loramie Creek upstream from Lake Loramie. This moraine serves locally as a major drainage divide. Northwest of the divide, water drains toward the St. Marys River which flows northwest into Indiana where it empties into the Maumee River. The Maumee River ultimately empties into Lake Erie at Toledo. This area drained by tributaries of the St. Marys River includes most of Van Buren Township and small portions of McLean Township and Dinsmore Township.

Pre- and Inter-Glacial Drainage and Topography

The pre-glacial and inter-glacial drainage of Shelby County is complex and is not yet fully understood. Part of the reason for this is the lack of well log data in which wells penetrate the entire thickness of drift filling the buried valleys and encounter bedrock at the valley floors. More research and data are necessary to answer many of the questions which remain.

Prior to glaciation, Shelby County was drained by the Teays Drainage System. The Teays River originated in the Appalachians and flowed northwest, entering Ohio near Portsmouth. Once in Ohio, the Teays flowed due north, roughly paralleling the present course of the Scioto River. In northern Pickaway County, the Teays veered to the northwest, flowing toward Springfield in Clark County. The Teays River entered Shelby County to the south and east of Port Jefferson and remained on a northwest course, exiting the county west of Botkins in Van Buren Township (Figure 4a). Continuing northwestward, the Teays River flowed through Auglaize County and Mercer County, entering Indiana west of town of Celina.

A tributary roughly following the course of the present Great Miami River flowed northeastward, joining the Teays River near Port Jefferson. The length and drainage area of this tributary has long been debated by geologists. Wayne (1952) and Durrell (1977) theorized that drainage within the ancestral Great Miami River flowed to the northeast and originated south of Cincinnati. Stout et al. (1943) and Norris and Spieker (1966) determined that there was a major drainage divide in far northeastern Montgomery County and that only areas north of this divide drained into the Teays. Clinch (1991), using abundant recent well log data, favored the theory of Stout et al. (1943) that the majority of the drainage area in the ancestral Great Miami River Valley was south of this divide and therefore flow was to the south.

Other, deeply-incised tributary valleys are found in western Shelby County. One of these valleys loops northward through Loramie Township and Washington Township. Another fairly deep buried extends through McLean Township west of Loramie Creek. The majority of Jackson Township, Dinsmore Township, and Salem Township are underlain by thick drift. These areas probably reflect a long history of downcutting by numerous, overlapping drainage systems.

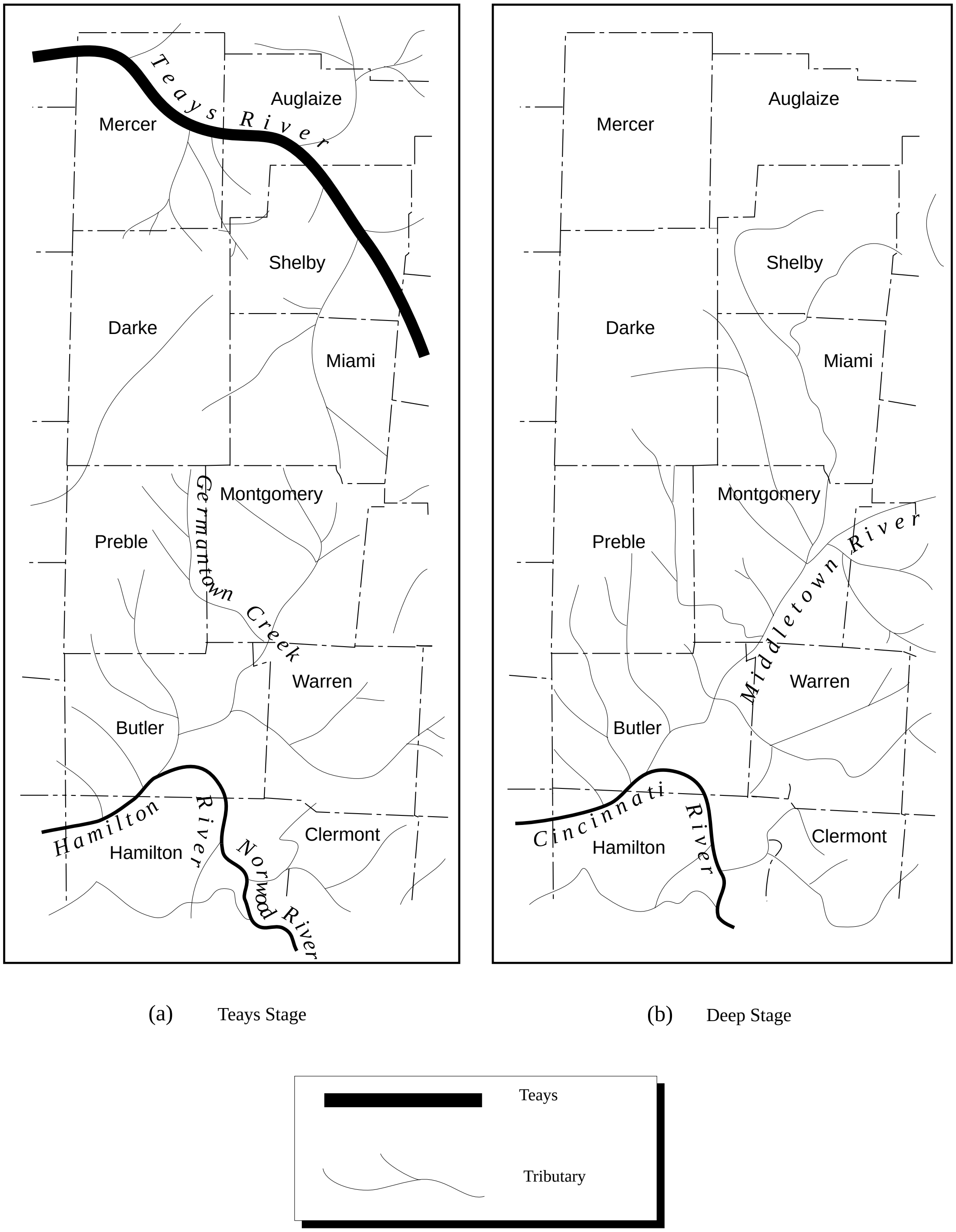
As ice advanced through Ohio during the pre-Illinoian (Kansan) glaciation, the Teays Drainage System was blocked. Flow backed up in the main trunk of the Teays Valley as well as in many tributaries, forming several large lakes. These lakes over-topped, creating spillways and cutting new channels. New drainage systems began to evolve (Stout et al., 1943). This downcutting by the streams was believed to be relatively rapid and, in many places, the new channels were cut over 100 feet deeper than the previous Teays System valleys. This new drainage system is referred to as the Deep Stage due to this increased downcutting (Figure 4b). Eventually, the drainage divide in northeastern Montgomery County was breached and the southwesterly course of the ancestral Great Miami River was established through Miami County and Shelby County.

The Illinoian glaciation further modified drainage systems in Shelby County. The Teays Valley and its tributaries were filled ("buried") with a variety of glacial sediment including lake (lacustrine) clays, clayey glacial till, and sandy to gravelly outwash. It is important to note that the aquifer characteristics of the Teays River Valley vary considerably due to the variability of these deposits.

The last ice advance, the Wisconsinan, greatly modified the surface topography of Shelby County and was largely responsible for the complex network of moraines found throughout the county. The Wisconsinan ice further modified valleys by erosion, deposition, and blockage of streams. Meltwater derived from these ice sheets also alternatively led to further erosion or deposition within valleys and drainage systems.

Glacial Geology

During the Pleistocene Epoch (2 million to 10,000 years before present {Y.B.P.}), several episodes of ice advance occurred in western Ohio. Table 9 summarizes the Pleistocene deposits encountered in Shelby County. Older ice advances are now conventionally referred to as pre-Illinoian (formerly Kansan). Deposits are determined to be pre-Illinoian if they predate the most recent (Brunhes) magnetic reversal (about 730,000 Y.B.P.). Evidence for these deposits is lacking at the surface and cores of adequate depth are lacking for identifying



(a) Teays Stage (b) Deep Stage

Figure 4. Teays and Deep Stage Drainage in Western Ohio (modified from Stout et al., 1943)

these units in the sub-surface. Stout et al. (1943) and Forsyth (1956) have speculated that deposits of this age should exist in the Teays Valley. More research is needed to determine the age of deposits at the base of the deeper valley systems. The effects of glacial advances upon pre-existing drainage have been documented in the previous section. This discussion will focus on glacial deposits, processes, and landforms.

Illinoian deposits have been determined to be at least 120,000 Y.B.P. in age. Forsyth speculated that deposits of this age probably were present at the base of deeper stream exposures, sand and gravel pits, and quarries. Forsyth (1956 and 1965a) proposed that the basal units of the till exposures near Sidney were early Wisconsinan in age and that a weathering profile developed in some of these tills was believed to represent an interval of weathering during the middle Wisconsinan. Current thinking (Eyles and Westgate, 1987 and Szabo and Totten, 1995) suggests that there was probably insufficient ice available in North America for a major ice advance into the Great Lakes area until the Late Wisconsinan Woodfordian sub-stage (approximately 25,000 Y.B.P.). The age of deposits previously determined to be early to mid-Wisconsinan in age needs to be re-evaluated. Miller et al. (1992) have proposed that the basal tills in the Sidney area are Illinoian in age. The cores of many of the end moraines are probably also composed of Illinoian -age tills.

The majority of the glacial deposits fall into four main types: (glacial) till, lacustrine, outwash, and ice-contact sand and gravel (kames). Buried valleys may contain a mix of all of these types of deposits. Drift is an older term that collectively refers to the entire sequence glacial deposits.

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.

The surficial tills of Shelby County are all assumed to be Late Wisconsinan (Woodfordian) in age (Lehman et al., 1980). These tills were deposited by the Miami Lobe which represented the westernmost segment of ice advance into Ohio (Forsyth, 1956).

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. Areas of ground moraine ("till plains") are limited mostly to the portion of the county southeast of the Great Miami River. End moraines are more ridge-like, with terrain that is steeper and more rolling or hummocky. Streams tend to parallel the margins of the moraines which helps to enhance the relief and steepness and hummockiness of these features. Locally, end moraines commonly serve as drainage divides.

End moraines commonly represent a thickening of till. Thicknesses of till in end moraines (not including drift in underlying buried valleys) ranges from roughly 40 to 80 feet. Such a thickening may have occurred along the edge of a glacier that was melting or "retreating". The ice would carry sediment to the edge where it would be deposited somewhat in conveyor-belt fashion. Conversely, an end moraine may be deposited by an advancing ice sheet. As the ice sheet hits an obstruction such as a hill or ridge, a thicker wedge of till is deposited. This wedge then serves as an obstruction for successive, over-riding ice sheets.

End moraines found in Shelby County from north to south include the St. Johns Moraine, the Mississinnewa Moraine, the Bloomer Moraine, and the Union City Moraine (Goldthwait et al., 1961). Forsyth (1956) differentiates the Sidney Moraine from the Bloomer Moraine

A very thorough discussion on all of the moraines and landforms is presented by Forsyth (1956) in her dissertation. The terrain developed upon the St. Johns Moraine is particularly hummocky with many small depressions, knobs, and swales. This topography is particularly noticeable in the vicinity of Botkins.These features may suggest that the St. Johns Moraine, at least near the surface, may be more ablational in nature.

The Farmersville Boulder Belt is found in the relatively flat-lying corner of the county southeast of the Great Miami River. This feature contains an unusually high number of large, erratic boulders of igneous and metamorphic origin at the land surface. In some areas, the Farmersville Boulder Belt coincides with an end moraine, in other areas, it is found in flat-lying areas. There has been much speculation as to the origin of the Boulder Belt (Forsyth, 1956), however, the cause has not yet been determined.

The nature of the till changes south of the Union City (and Sidney) Moraine. The till to the south of the moraine tends to be somewhat coarser-textured with more sand and silt, and less clay on average then the till found north of this moraine (Forsyth, 1956, Forsyth, 1965b, Steiger and Holowaychuk, 1971 and Selby, 1978). In Darke County, Selby (1978) referred to the finer-grained tills north of the Union City Moraine as the Woodington Till and Yorkshire Till and the loamier till south of the moraine as the Arcanum Till. Well logs indicate a higher proportion of shallow sand and gravel lenses in the St. Johns Moraine than in the other moraines. The increased number of sand and gravel lenses together with the more hummocky nature of this landform may be another indication that the moraine may represent more of an ablational feature.

Lacustrine deposits were created as a result of the formation of numerous shallow lakes. In some locales, the lakes may have coalesced together forming deeper, more areally extensive lakes. Within stream valleys, lakes were formed by the damming of streams by advancing ice sheets. The Teays River Valley and its tributaries may contain appreciable thicknesses of lacustrine deposits (Stout et al., 1943). These fine-grained deposits represent the initial damming and blockage of the Teays Valley by the advancing ice sheet. These deposits are referred to as the Minford Silts and have been found occupying many other deep valleys in central and southeastern Ohio. In ground moraine areas, lakes were formed as meltwater was trapped between the melting ice sheet and adjacent, previously-deposited moraines. In some low-lying areas, lakes formed as the ice melted quicker then drainage systems could evolve. Deposits from shallow, inter-morainal lakes are also referred to as slackwater deposits. Typically, lacustrine deposits are composed of fairly dense, cohesive, uniform silt and clay with minor fine sand. Thin bedding, referred to as laminations, are common in these deposits. Such sediments were deposited in quiet, low-energy environments with little or no current.

Table 9. Glacial Stratigraphy of Shelby Count, Ohio (After Selby, 1978)

AGE (years ago)	EPOCH	STAGE		SUBSTAGE	UNIT OR INTERVAL
25, 000	PLEISTOCENE	WISCONSINAN	LATE	Wood-fordian	Yorkshire Till Woodington Till Arcanum Till
40,000			MIDDLE	Farmdalian (1)	Sidney Weathering Interval
70,000			EARLY	Altonian (1)	Unknown ?
120,000		SANGAMONIAN			Unknown ?
730,000		ILLINOIAN			Whitewater Till
2,000,000		PRE-ILLINOIAN			Unknown ?

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 Shelby County are predominantly located in stream valleys. Such deposits 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. Outwash is usually deposited by braided streams. Such streams have multiple channels which migrate across the width of the valley floor, leaving behind a complex record of deposition and erosion. As modern streams downcut, the older, now higher elevation, remnants of the original valley floor are called terraces. Excellent example of outwash terraces are found along the Great Miami River and Plum Creek in the Sidney area and along portions of Loramie Creek in Washington Township (Forsyth, 1956 and Lehman et. al, 1980).

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. Forsyth (1956) mapped a number of kames paralleling the south side of Mosquito Creek. These kames tend to coalesce together along the valley margins. Such features are referred to as kame terraces. They represent deposition of materials between the melting ice sheet and the bedrock and till slopes flanking the ice-filled valleys.

Peat and muck are organic-rich deposits associated with low-lying depressional areas, bogs, kettles, and swamps. Muck is a 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, along with lacustrine or slackwater clays and silts. The majority of these deposits are found along lower-lying portions of valley floors including margins of floodplains and terraces. Smaller kettle type features containing muck and peat are also found in upland depressions found in end moraines or small pockets "trapped" between moraines.

Bedrock Geology

The bedrock geology of Shelby County is composed of upper Ordovician to upper Silurian rocks. Table 10 summarizes the bedrock stratigraphy of Shelby County. The oldest rocks are thin, interbedded calcareous shales and limestones of the Late Ordovician. These units are not observable at the ground surface within the county. They are found at the floors of the deeper buried valley systems within Shelby County.

Table 10. Bedrock Stratigraphy of Shelby County, Ohio. (After Schumacher, 1993)

SYSTEM	SERIES	STRATIGRAPHIC UNIT
SILURIAN 425—405 Million Years Ago	Cayugan	Salina undifferentiated
	Niagaran	Lockport Dolomite
	Alexandrian	Sub-Lockport
ORDOVICIAN 500—425 Million Years Ago	Cincinnatian	Ordovician Undivided

Sedimentation during the Late Ordovician was influenced by the Cincinnati Arch, a broad, gently-sloping ridge which roughly extended from Cincinnati to north of Findlay. Deposition of sediment occurred in a shallow marine shelf environment along the rise associated with the Arch. Limestones were deposited in these clear waters containing abundant life. Shaley units reflect fine terrigenous (i.e. "land-derived") sediments which were washed in to the basin during major storm events. These finer sediments are believed to come from areas experiencing rapid uplift well to the east of the Arch. Schumacher et. al (1987) and Schumacher et. al (1991) provide more detailed descriptions on the cyclical nature of the deposits. Deep core data from the west central Ohio indicates that there is a major unconformity or break between Ordovician and Silurian units throughout this region. Bedrock units exposed along the Great Miami River and in adjacent quarries south of Sidney contain limestones and dolomites (collectively referred to as carbonates) of the Sub-Lockport and Lockport. The Sub-Lockport contains minor thin shales and thicker sequences of limestone and shale. Forsyth (1956), utilizing the terminology of the time, referred to these units as the Brassfield and the Cedarville. The Sub-Lockport is typically found underlying the margins or flanks of the deeper buried valley systems in the county. Deposition of the rocks in the Sub-Lockport show a transitional change to more stable, shallow marine, warm water environment.

Limestones and dolomites of the Lockport are found throughout many portions of Shelby County. Exposures are primarily limited to quarries due to the typically thick glacial cover. The Lockport rocks are commonly found underlying areas outside of the major buried valleys. The Lockport is composed of fine-grained, whitish to grayish limestones and dolomites. The units may be moderately fossiliferous and contain vuggy ("more porous") zones. These sediments were deposited in warm, shallow, moderately high-energy environments. Reef facies appear to have been common at this time.

The youngest bedrock units encountered within Shelby County belong to the Upper Silurian Salina Undifferentiated. These units are generally found in upland area which lie between the major buried valleys. The Salina Undifferntiated is composed of a complex sequence of fine-grained, whitish to light brown dolomites and limestones. Impure shaley and gypsum beds are found within this unit. Traces of algal mats are also common and indicate a tendency toward shallowing seas. Horvath and Sparling (1967), Janssens (1977), and Kleffner and Ausich (1988), give detailed descriptions of Silurian rocks in western Ohio.

Hydrogeology

Ground water in Shelby County is derived from both glacial (unconsolidated) and bedrock (consolidated) aquifers. Glacial deposits are utilized as aquifers within the buried valleys. Sand and gravel lenses interbedded with glacial till in areas of end moraine are commonly utilized as aquifers in much of northern and western Shelby County. Bedrock is utilized as the aquifer where the glacial deposits are too thin or too fine-grained. The Silurian Lockport and Salina Undifferentiated are selectively utilized by many drillers due to their high productivity and the relative ease of developing wells in these formations.

Yields from glacial aquifers in Shelby County are highly variable, particularly within the buried valleys. Aquifers range from thin, isolated lenses of sand and gravel interbedded in thick sequences of glacial till or lacustrine deposits to thick sequences of coarse, well-sorted sand and gravel outwash terraces in close proximity to modern streams. The highest yielding aquifers are the thick sequences of sand and gravel outwash found in the lower portions of

Turtle Creek and Loramie Creek in Washington and Loramie Township. Properly designed, large diameter wells have the capability of sustaining yields up to 500 gallons per minute (gpm) in these areas (Kostelnick, 1983). Test drilling is recommended to find the highest-yielding intervals. Outwash deposits flanking Lake Loramie and outwash deposits along the Great Miami River from Sidney northwards are capable of providing sustained yields in excess of 100 gpm (Kostelnick, 1983). Thicker layers of sand and gravel buried at depth in the main axis of the Teays Valley and the deep tributary valley in western McLean Township also can produce sustained yields exceeding 100 gpm (Kostelnick, 1983). Yields of 10 to 25 gpm (Kostelnick, 1983) are common in many of the other buried valleys within Shelby County. These valleys are primarily infilled with till instead of thick sequences of outwash. These valleys also tend to lack modern streams at the surface. Yields in some segments of buried valleys in southern Shelby County average less than 10 gpm (Kostelnick, 1983). Wells in these areas utilize thin, discontinuous lenses of sand and gravel interbedded in thicker sequences of till or lacustrine sediments.

Limestones and dolomites of both the Lockport and Salina Undifferentiated are capable of averaging 25 gpm or better (Division of Water, 1970 and Kostelnick, 1983). Maximum yields over 150 gpm have been reported from higher productive zones in the Lockport and the Salina Undifferentiated (Division of Water, 1970 and Kostelnick, 1983). These higher yields are typically related to areas where the bedrock is more fractured, particularly stream valleys and areas in which the limestone contains more solution features. Yields also tend to be higher where modern streams overly the aquifer and provide additional recharge.

Limestones, dolomites, and shales of the Sub-Lockport are much lower-yielding aquifers than the overlying units. These units are rarely utilized in Shelby County as wells are typically developed at some interval in the thick overlying drift. The interbedded limestones and shales of the Ordovician constitute very poor aquifers. These units are not utilized as aquifers in Shelby County due to the thick sequences of more productive glacial drift.

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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 4,000 water well log records are on file for Shelby County. Data from roughly 1,000 water well log records were plotted on U.S.G.S. 7-1/2 minute topographic maps during the course of the project. Static water levels and information on the depth of saturated zones were taken from these records. The Ground Water Resources of Shelby County (Kostelnick, 1983) provided generalized depth to water information throughout the county. The report of Eagon (1972) provided detailed water level data for portions of Salem Township. Topographic and geomorphic trends were utilized in areas where other sources of data were lacking.

Depths to water of 0 to 5 feet (DRASTIC value = (10)) were limited to certain low-lying stream drainages in the far eastern margin of the county. Depths to water of 5 to 15 feet (9) were typical of areas adjacent to upland streams, along floodplains and low terraces of larger streams, and in broad valley floors which contained streams. Depths to water of 5 to 15 feet were commonly found in the vicinity of Lake Loramie. Depths to water of 15 to 30 feet (7) were common in the gently rolling to moderately flat areas of ground moraine, along the higher level terraces bordering stream valleys, and flanking smaller, relatively deeply-incised streams in upland areas. Depths to water of 30 to 50 feet (5) were commonly found in areas of end moraine and in buried valleys containing moderately deep wells. Areas utilizing bedrock for an aquifer generally had a depth to water of 30 to 50 feet (5) due to the moderately thick glacial cover. Depths to water of 50 to 75 feet (3) and 75 to 100 feet (2) were limited to areas with very deep wells. These areas included crests of major end moraines, deeper aquifers within buried valleys, and areas where end moraines coincidentally overlie buried valleys.

Net Recharge

This factor was evaluated using many criteria, including depth to water, topography, soil type, surface drainage, vadose zone material, and annual precipitation. Recharge is the precipitation that reaches or recharges the aquifer after losses to evapotranspiration and runoff. General estimates of recharge provided by Pettyjohn and Henning (1979) proved to be helpful.

Values of 7 to 10 inches per year (8) of recharge were assigned to areas with highly permeable soils and vadose materials, shallow depths to water, gentle slopes, and surficial streams. These areas were typically limited to areas containing abundant coarse outwash including terraces and floodplains. This rating was also utilized for portions of the Great Miami River south of Sidney where fractured bedrock is very close to the surface. Such areas are typically adjacent to modern streams. Values of 4 to 7 inches per year (6) of recharge were commonly utilized throughout much of the county. This included many area of end moraine and ground moraine, areas along margins of buried valleys, and along streams in upland areas overlying finer-grained soils. Recharge values of 2 to 4 inches per year (3) were assigned to areas with a great depth to water, thick cover of fine-grained, dense till, clayey soils,and moderate slopes. These area typically are at the crest of moraines or lie near the axis of buried valleys predominantly filled with fine-grained materials. Modern surface drainage is usually lacking in these areas.

Aquifer Media

Information on aquifer media was obtained from the reports of Stout et. al (1943), Forsyth (1956), Division of Water (1970), and Kostelnick (1983). Information on the bedrock topography and drift thickness on a county-wide basis were provided by Peterson and Vormelker (1991a and 1991b, respectively. Cummins (1959) also provided information on regional bedrock topography. Regional information on bedrock was provided by Schumacher (1993). Preliminary open file reconnaissance bedrock geology maps from the ODNR, Division of Geological Survey proved to be tremendously valuable in differentiating bedrock units within the county. This mapping was done at a scale of 1:24,000 and included the maps of Schumacher (1991a-l). Open file reconnaissance bedrock topography maps from the ODNR, Division of Geological Survey proved to be invaluable in delineating buried valleys and mapping aquifer media. This mapping was done at a scale of 1:24,000 and included the maps of Clinch and Vormelker (1991), Schumacher (1991m-q), and Vormelker (1991a-f).

An aquifer rating of (7) was utilized for aquifers within the Lockport and Sub-Lockport. An aquifer rating of (8) was used for aquifers within the Salina Undifferentiated as solution features appear to be more prevalent in these units. These ratings conform to those utilized in surrounding counties including Mercer County (Sugar, 1989), Darke County (Spahr, 1991), Miami County (Spahr, 1995), Champaign County (Jones, 1995) and Logan County (Sprowls, 1995).

Ratings for the aquifers in glacial deposits varied within Shelby County. An aquifer rating of (6) was commonly used for aquifers comprised of sand and gravel lenses interbedded with glacial till. This rating applies to aquifers in both moraine areas as well as buried valleys. An aquifer rating of (7) was assigned to sand and gravel aquifers comprised of thicker sequences of sand and gravel outwash. This includes both surficial outwash terrace deposits as well as thicker outwash deposits occurring at depth within buried valleys. Sand and gravel aquifers with a rating of (7) included those underlying portions of Loramie Creek, Turtle Creek, Mosquito Creek, terraces along the Great Miami River Valley, and portions of the Teays Valley and the valley in western McLean Township. An aquifer rating of (8) was utilized for localized outwash deposits which extend northward from the confluence of Loramie Creek and the Great Miami River in Miami County.

Soil Media

This factor was primarily evaluated using data obtained from the Soil Survey of Shelby County (Lehman et. al, 1980). Table 11 lists the soil types encountered in Shelby County and gives information on the soils' parent material or setting and the corresponding DRASTIC rating. The nature of the underlying glacial material was the primary factor influencing soil types in Shelby County. Soil ratings were based upon the most restrictive layer or horizon within the soil profile.

Table 11. Shelby County Soils

Soil Name	Parent Material or Setting	DRASTIC Rating	Soil Media
Algiers	alluvium, floodplain	4	silt loam
Blount	till	3	clay loam
Brookston	till	3	clay loam
Carlisle	kettles, bogs	8	peat
Celina	till	3	clay loam
Crane	alluvium, floodplain	4	silt loam
Crosby	till	3	clay loam
Eel	alluvium, floodplain	4	silt loam
Eldean	outwash, kames	6	sandy loam
Genesee	alluvium, floodplain	4	silt loam
Glywood	till	3	clay loam
Medway	alluvium, floodplain	4	silt loam
Miamian	till	3	clay loam
Milton	limestone	10	thin or absent
Montgomery	slackwater, lacustrine	7	shrink/swell clay
Morley	till	3	clay loam
Ockley	outwash terrace	6	sandy loam
Odell	till	3	clay loam
Patton	slackwater, lacustrine	7	shrink/swell clay
Pewamo	till	3	clay loam
Shoals	alluvium, floodplain	4	silt loam
Stonelick	coarse alluvium	6	sandy loam
Wallkill	bogs, kettles	8	peat
Warsau	outwash, kames	6	sandy loam

Clay loam (3) was the most common soil rating utilized in Shelby County. Clay loam was encountered in areas where glacial till was the surficial material including ground moraine and end moraine. Clay loam was also found in some alluvial and lacustrine/slackwater deposits in upland areas. Silt loam (4) was common in modern floodplains and low-lying alluvial terraces. Sandy loam (6) was associated with outwash terraces, valley trains, and kames. Shrink-swell (aggregated) clays were developed upon slackwater deposits along upland streams and in depressions between ridges or steep hummocks associated with end moraines. Peat (8) soils were found in a few isolated kettles overlying outwash deposits or occupying small depressions on end moraines.

Topography

Topography was evaluated by determining the percentage of slope obtained from the U.S.G.S. 7-1/2 minute (1:24,000 scale) quadrangle maps and from the Soil Survey of Shelby County (Lehman et. al, 1980). Slopes of 0 to 2 percent (10) were selected for floodplains, terraces, and areas of ground moraine. Slopes of 2 to 6 percent (9) were common along the crests and flanks of the more gently-sloping end moraines as well as some areas of ground moraine and terraces. Slopes of 6 to 12 percent (5) were utilized for the more steeply-sloping end moraines, kames, and areas that are highly dissected by streams. Slopes of 12 to 18 percent (3) were assigned to very steep slopes which typically flanked deeply-incised streams in highly dissected, upland areas.

Impact of the Vadose Zone Media

Water well log records on file at the WRS were a primary source of information on vadose zone media. Other information on vadose zone media was obtained from the reports of Stout et. al (1943), Forsyth (1956 and 1965a), Division of Water (1970), and Kostelnick (1983). Information on the bedrock topography and drift thickness on a county-wide basis were provided by Peterson and Vormelker (1991a and 1991b, respectively. Cummins (1959) also provided information on regional bedrock topography. Regional information on bedrock geology was provided by Schumacher (1993). Preliminary open file reconnaissance bedrock geology maps from the ODNR, Division of Geological Survey proved to be tremendously valuable in differentiating bedrock units within the county. This mapping was done at a scale of 1:24,000 and included the maps of Schumacher (1991a-l). Open file reconnaissance bedrock topography maps from the ODNR, Division of Geological Survey proved to be invaluable in delineating buried valleys and mapping aquifer media. This mapping was done at a scale of 1:24,000 and included the maps of Clinch and Vormelker (1991), Schumacher (1991m-q), and Vormelker (1991a-f).

Till was selected as the vadose zone media for most of Shelby County including most areas of ground moraine, end moraine, and buried valleys which lack outwash or alluvial fill at the surface. Typically a rating of (4) was assigned to the till. Where the thickness of till and the depth to water both exceeded 50 feet, a rating of (3) was utilized for the till. As the depth to water increases, the majority of the till becomes unweathered, fracturing within the till decreases significantly, and with increasing thickness, the compaction and density of the till tends to increase. All of these factors tend to make the till less permeable and limit possible conduits of contamination.

Sand and gravel with significant silt and clay was selected as the vadose zone media for portions of the St. Johns Moraine and Mississinnewa Moraine which exhibited the hummocky ablational topography and for areas where well logs reported more shallow sands and gravels.

A vadose zone media rating of (5) was applied to these areas. Sand and gravel with significant silt and clay was selected as the vadose zone media and ratings of (5) and (6) were utilized for areas containing outwash, kames, and coarser alluvial deposits. The varied ratings were based upon the relative proportion of sand and gravel and the relative coarseness and degree of sorting within the sand and gravel units. Ratings of (4) and (5) were chosen for silt and clay which was selected as the vadose zone media for alluvium and floodplains. Silt and clay with ratings of (3) and (4) were also utilized for areas with lacustrine/slackwater deposits at or near the surface.

Bedrock was chosen as the vadose zone media for areas flanking the Great Miami River south of Sidney where bedrock is in very close proximity to the surface. The limestones were assigned vadose zone media ratings of (7) and (8) depending upon the nature of the underlying bedrock aquifer.

Hydraulic Conductivity

Published data for hydraulic conductivity was lacking for Shelby County. Information from the Division of Water (1970) and Kostelnick (1983) proved to be useful for inferring values for hydraulic conductivity. Hydraulic conductivity values utilized in surrounding counties including Mercer County (Sugar, 1989), Darke County (Spahr, 1991), Miami County (Spahr, 1995), Champaign County (Jones, 1995) and Logan County (Sprowls, 1995) were largely extended into Shelby County. Water well log records at the WRS were carefully reviewed. Textbook tables (Freeze and Cherry, 1979; Fetter, 1980; and Driscoll, 1986) were useful in obtaining estimated values for hydraulic conductivity for a variety of sediments.

Values for hydraulic conductivity roughly followed the aquifer ratings; i.e., the more highly rated aquifers have higher hydraulic conductivities. For sand and gravel aquifers, the hydraulic conductivity is a function of coarseness, stratification (bedding), sorting, and cleanliness (absence of fines). For sand and gravel aquifers with an aquifer media rating of (6), ranges for hydraulic conductivity varied from 100-3000 gallons per day per square foot (gpd/ft^2) (2) to 300-700 gpd/ft^2 (4). Values of hydraulic conductivity ranging from 300-700 gpd/ft^2 (4) to 700-1,000 gpd/ft^2 (6) were selected for sand and gravel aquifers with an aquifer media rating of (7). Values for hydraulic conductivity for sand and gravel deposits with an aquifer media rating of (8) ranged from 700-1,000 gpd/ft^2 (6).

Hydraulic conductivity values ranging from 300-700 gpd/ft^2 (4) were utilized for the carbonate bedrock aquifers. Hydraulic conductivity values ranged from 700-1,000 gpd/ft^2 (6) for the shallow bedrock along the Great Miami River south of Sidney. This bedrock is highly fractured and is more weathered due to its close proximity to the surface.

The range of ratings for sand and gravel with significant silt and clay as a vadose material varied from (4) to (7). Over outwash areas and kame areas, this media was rated (6) or (7), depending upon the amount of silt or clay present. In buried valley areas where there were notable deposits of sand and gravel interbedded in the till, this media was rated (4) or (5).

Till was selected as the vadose zone material in most areas of ground moraine or end moraine, and in buried valley areas lacking significant outwash. The typical rating for this media was (4), although in some areas it was rated (5) due to a higher content of coarser-grained particles. Clays and silty clays, such as those found in buried valley, lake bed, and alluvial deposits, were rated (3) and (4), respectively.

Limestone as a vadose material was generally rated a (6). In some areas of the outlier it was rated a (3) or (4). Shale was also selected as the vadose material in the area of the outlier and rated a (3) because of its thickness and fine-grained nature, as well as relative lack of fracturing.

APPENDIX B

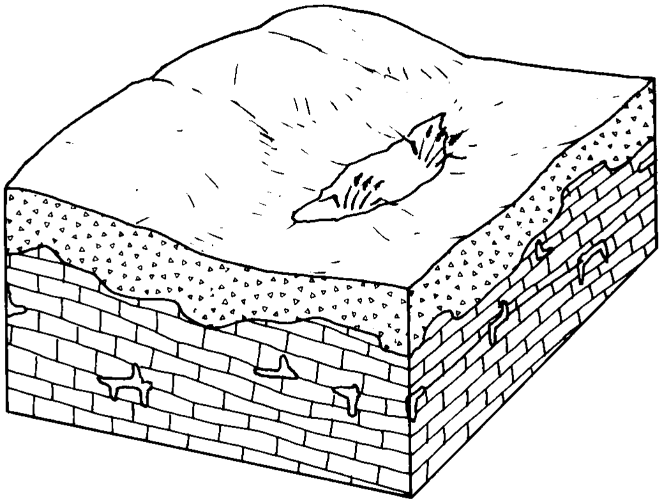
DESCRIPTION OF HYDROGEOLOGIC SETTINGS AND CHARTS

Ground water pollution potential mapping in Shelby County resulted in the identification of six hydrogeologic settings within the Glaciated Central Region. The list of these settings, the range of pollution potential index calculations, and the number of index calculations for each setting are provided in Table 12. Computed pollution potential indexes for Shelby County range from 83 to 189.

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

Hydrogeologic Settings	Range of GWPP Indexes	Number of Index Calculations
7Ac - Glacial Till Over Limestone	90 - 141	22
7Af - Sand/Gravel Interbedded in Glacial Till	83 - 153	33
7Bc - Outwash Over Limestone	158 - 189	7
7D - Buried Valley	83 - 171	80
7Ec - Alluvium Over Sedimentary Rock	128 - 159	7
7Ed - Alluvium Over Glacial Till	127 - 161	13
7Ee - Alluvium Over Outwash	135 - 164	5

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



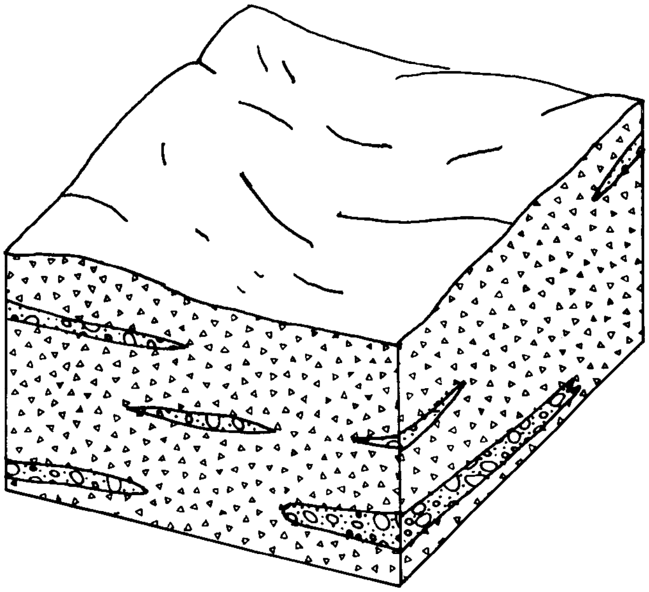
7Ac Glacial Till Over Limestone

This hydrogeologic setting was used in central and western portions of Shelby County. The area is characterized by rolling, hummocky end moraine which overlies the limestone bedrock. The aquifer is the Silurian limestones and dolomites. Ground water occurs in fractures, solution features, and vuggy zones. Yields for domestic wells typically range from 15 to 30 gpm and large diameter wells are capable of producing up to 500 gpm if major fracture systems are encountered. The overlying glacial till consists primarily of clay, silt, sand, and gravel. Sand and gravel lenses within the till are numerous but are too thin and discontinuous to constitute an aquifer. Some well drillers preferentially "by-pass" the sand and gravel lenses as it is easier to complete and develop wells in the bedrock. The thickness of the till ranges from less than 20 feet to over 100 feet in areas underlying moraines or peripheral to major buried valleys. Depth to water is highly variable and depends in part upon the thickness of the till and the proximity of surficial streams. Soils are typically clay loams. Precipitation infiltrating through the till serves as the source of recharge to the bedrock. Recharge is moderate to low and depends upon the thickness of the till, depth to water, proximity of streams, and slope.

The GWPP index values for the hydrogeologic setting of Glacial Till Over Limestone range from 90 to 141 with the total number of GWPP calculations equaling 22.

Setting	Depth to Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pest Rating
7Ac1	15	2-4	Solution limestone	Clay Loam	2-6	Till	300-700	93	113
7Ac2	25	4-7	Solution limestone	Clay Loam	2-6	Till	300-700	120	139
7Ac3	25	4-7	Massive limestone	Clay Loam	0-2	Till	300-700	118	139
7Ac4	25	4-7	Massive limestone	Clay Loam	2-6	Till	300-700	117	136
7Ac5	35	4-7	Massive limestone	Clay Loam	0-2	Till	300-700	128	149
7Ac6	35	4-7	Solution limestone	Clay Loam	0-2	Till	300-700	131	152
7Ac7	45	4-7	Solution limestone	Clay Loam	0-2	Till	300-700	141	162
7Ac8	25	4-7	Solution limestone	Clay Loam	0-2	Till	300-700	121	142
7Ac9	45	4-7	Massive limestone	Clay Loam	0-2	Till	300-700	138	159
7Ac10	25	4-7	Massive limestone	Clay Loam	0-2	Sand and gravel w/ silt and clay	300-700	123	143

Setting	Depth to Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pest Rating
7Ac11	25	4-7	Massive limestone	Clay Loam	2-6	Sand and gravel w/ silt and clay	300-700	122	140
7Ac12	35	4-7	Massive limestone	Peat	0-2	Sand and gravel w/ silt and clay	300-700	143	178
7Ac13	45	4-7	Massive limestone	Shrinking and/or Aggregated Clay	0-2	Silt/clay	300-700	141	175
7Ac14	25	4-7	Massive limestone	Clay Loam	6-12	Till	300-700	113	124
7Ac15	15	2-4	Massive limestone	Clay Loam	0-2	Till	300-700	91	113
7Ac16	15	2-4	Massive limestone	Clay Loam	2-6	Till	300-700	90	110
7Ac17	15	2-4	Solution limestone	Clay Loam	0-2	Till	300-700	94	116
7Ac18	25	4-7	Solution limestone	Clay Loam	12-18	Till	300-700	114	121
7Ac19	35	4-7	Massive limestone	Clay Loam	2-6	Till	300-700	127	146
7Ac20	25	4-7	Massive limestone	Clay Loam	12-18	Till	300-700	111	118
7Ac21	35	4-7	Massive limestone	Clay Loam	6-12	Till	300-700	123	134
7Ac22	35	4-7	Massive limestone	Clay Loam	12-18	Sand and gravel w/ silt and clay	300-700	126	132



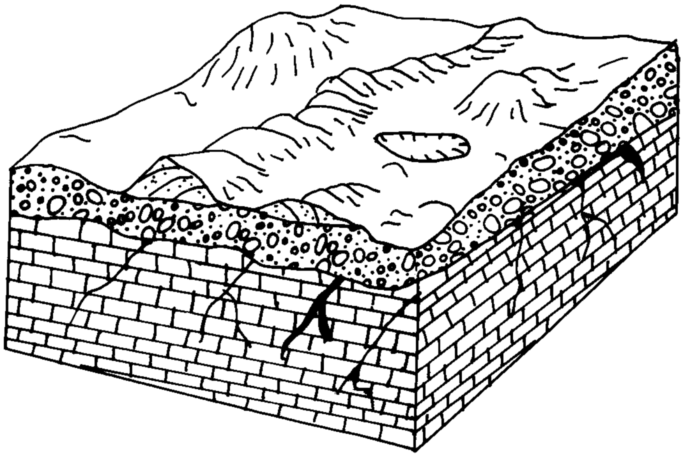
7Af Sand and Gravel Interbedded in Glacial Till

This hydrogeologic setting was utilized primarily in the central and western portions of Shelby County. Areas in this setting are typically transitional and lie between the thinner drift found in the 7Ac Glacial Till over Limestone and the thicker drift found in the 7D Buried Valley hydrogeologic setting. Topography is rolling and hummocky in areas of end moraine and flatter and less rolling in areas of ground moraine. The till is composed of a dense, compact mixture of clay, silt, sand, and gravel. The aquifer consists of relatively thin and discontinuous, lens-shaped bodies. In some areas, the sand and gravel may exist in thicker sheets that cover a larger area. Depth to water is typically moderate, ranging from 20 to 50 feet. Recharge is from precipitation percolating through the till and is dependent upon the presence of fractures and small sand seams within the till. Yields typically average from 10 to 20 gpm. Soils are typically clay loams. Recharge is moderate due to the moderate depth to water, moderate slope, and the relatively low permeability of the soil and glacial till.

The GWPP index values for the hydrogeologic setting of Sand and Gravel Interbedded in Glacial Till range from 83 to 153 and the total number of GWPP index calculations equaling 33.

Setting	Depth to Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pest Rating
7Af1	35	4-7	Sand and gravel	Clay Loam	0-2	Sand & gravel w/ silt & clay	300-700	133	153
7Af2	25	4-7	Sand and gravel	Clay Loam	0-2	Till	300-700	115	136
7Af3	25	4-7	Sand and gravel	Clay Loam	0-2	Sand & gravel w/ silt & clay	300-700	120	140
7Af4	25	4-7	Sand and gravel	Clay Loam	2-6	Sand & gravel w/ silt & clay	300-700	119	137
7Af5	35	4-7	Sand and gravel	Clay Loam	0-2	Till	300-700	125	146
7Af6	35	4-7	Sand and gravel	Clay Loam	0-2	Sand & gravel w/ silt & clay	300-700	130	150
7Af7	35	4-7	Sand and gravel	Sandy Loam	0-2	Sand & gravel w/ silt & clay	300-700	136	165

Setting	Depth to Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pest Rating
7Af8	35	4-7	Sand and gravel	Shrinking and/or Aggregated Clay	0-2	Till	300-700	133	166
7Af9	35	4-7	Sand and gravel	Clay Loam	0-2	Till	300-700	128	149
7Af10	45	4-7	Sand and gravel	Clay Loam	0-2	Sand & gravel w/ silt & clay	300-700	143	163
7Af11	45	4-7	Sand and gravel	Peat	0-2	Sand & gravel w/ silt & clay	300-700	153	188
7Af12	25	4-7	Sand and gravel	Clay Loam	2-6	Till	300-700	114	133
7Af13	15	2-4	Sand and gravel	Clay Loam	2-6	Till	300-700	87	107
7Af14	45	4-7	Sand and gravel	Clay Loam	0-2	Till	300-700	135	156
7Af15	45	4-7	Sand and gravel	Clay Loam	0-2	Till	300-700	138	159
7Af16	25	4-7	Sand and gravel	Clay Loam	0-2	Till	300-700	118	139
7Af17	35	4-7	Sand and gravel	Clay Loam	6-12	Till	300-700	123	134
7Af18	25	4-7	Sand and gravel	Clay Loam	2-6	Till	300-700	117	136
7Af19	25	4-7	Sand and gravel	Clay Loam	12-18	Till	300-700	108	115
7Af20	15	2-4	Sand and gravel	Clay Loam	0-2	Till	300-700	88	110
7Af21	35	4-7	Sand and gravel	Clay Loam	2-6	Till	300-700	124	143
7Af22	35	4-7	Sand and gravel	Clay Loam	0-2	Till	100-300	119	142
7Af23	45	4-7	Sand and gravel	Clay Loam	0-2	Till	100-300	129	152
7Af24	15	2-4	Sand and gravel	Clay Loam	0-2	Till	300-700	91	113
7Af25	15	2-4	Sand and gravel	Clay Loam	2-6	Till	300-700	90	110
7Af26	25	4-7	Sand and gravel	Clay Loam	0-2	Till	100-300	109	132
7Af27	35	4-7	Sand and gravel	Clay Loam	6-12	Till	100-300	114	127
7Af28	35	4-7	Sand and gravel	Clay Loam	0-2	Sand & gravel w/ silt & clay	700-1000	139	157
7Af29	35	4-7	Sand and gravel	Clay Loam	2-6	Till	300-700	127	146
7Af30	35	4-7	Sand and gravel	Clay Loam	6-12	Sand & gravel w/ silt & clay	300-700	120	131
7Af31	10	2-4	Sand and gravel	Clay Loam	0-2	Till	300-700	83	105
7Af32	35	4-7	Sand and gravel	Clay Loam	6-12	Sand & gravel w/ silt & clay	100-300	116	128
7Af33	25	4-7	Sand and gravel	Clay Loam	2-6	Sand & gravel w/ silt & clay	100-300	110	130

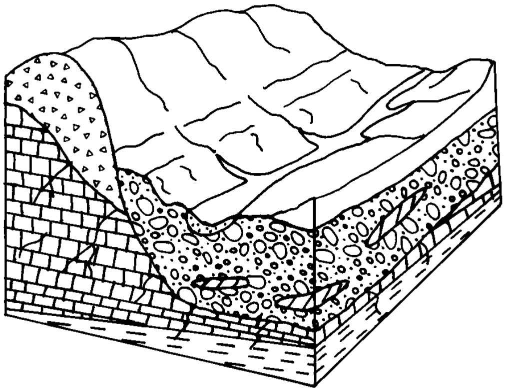


7Bc Outwash Over Limestone

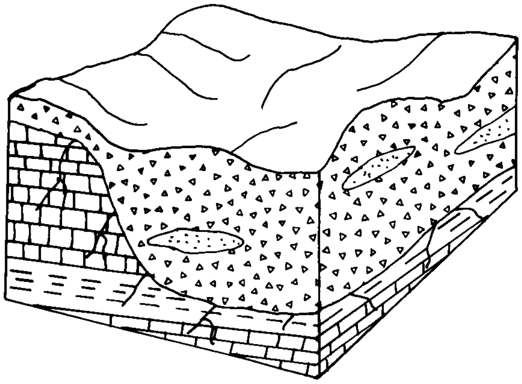
This hydrogeologic setting is limited to areas immediately adjacent to the Great Miami River south of Sidney. In these areas, low-lying terraces overlie the fractured limestone bedrock. Topography is relatively flat to gently rolling. The outwash is too thin to comprise the aquifer, therefore ground water is obtained from the underlying limestone bedrock. In a few limited areas, the outwash is very thin and the bedrock crops out at the surface. The outwash is in direct hydraulic connection with the underlying bedrock. Precipitation moving through the permeable outwash recharges the bedrock. Yields exceeding 100 gpm may be obtained from the underlying bedrock. Depths to water are typically less than 20 feet as these low terraces are adjacent to the Great Miami River. Soils vary and include silt loams, sandy loam, and soils developed in limestone bedrock. Recharge is moderately high due to the permeable soils and vadose, the shallow depth to water, and the flat topography.

The GWPP index values for the hydrogeologic setting Outwash Over Limestone range from 158 to 189 with the total number of GWPP index calculations equaling 7.

Setting	Depth to Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pest Rating
7Bc1	35	7-10	Massive limestone	Sandy Loam	0-2	Sand and gravel w/ silt and clay	700-1000	158	184
7Bc2	45	7-10	Solution limestone	Silty Loam	0-2	Sand and gravel w/ silt and clay	700-1000	167	187
7Bc3	35	7-10	Solution limestone	Sandy Loam	0-2	Sand and gravel w/ silt and clay	700-1000	161	187
7Bc4	45	7-10	Solution limestone	Thin or absent	0-2	Solution limestone	700-1000	189	225
7Bc5	45	7-10	Solution limestone	Sandy Loam	0-2	Sand and gravel w/ silt and clay	700-1000	171	197
7Bc6	45	7-10	Massive limestone	Thin or absent	0-2	Massive limestone	700-1000	181	218
7Bc7	45	7-10	Massive limestone	Sandy Loam	0-2	Sand and gravel w/ silt and clay	700-1000	168	194



(a)



(b)

7D Buried Valley

This hydrogeologic setting varied considerably across Shelby County. The buried valleys were created by pre-glacial (i.e.-Teays River System) or inter-glacial rivers which downcut into the bedrock. The differing glacial deposits filling these valleys can best be illustrated by describing the two common forms mapped within Shelby County.

One common form of buried valley (Block Diagram a) is exemplified by southern portions of Loramie Creek and the Great Miami River northeast of Sidney. These valleys are occupied by modern rivers and floodplains. The upper portions of these valleys contain over 50 feet of outwash. Depth to water is typically less than 20 feet. Yields up to 500 gpm are possible from large-diameter wells. Soils are usually sandy loams. The streams are in direct hydraulic connection with the aquifer and recharge is high.

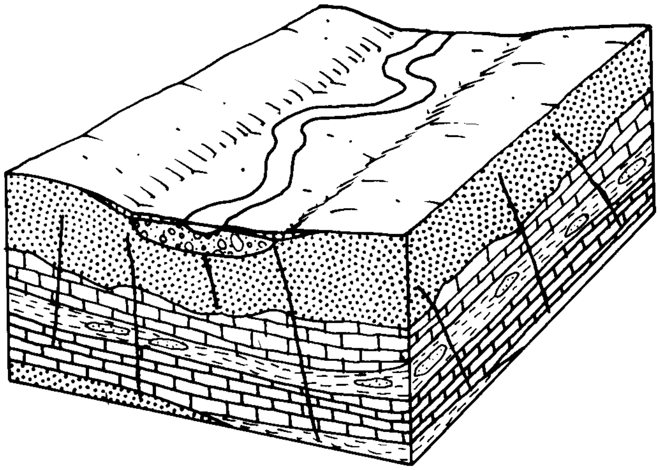
The other common form of buried valley (Block Diagram b) is typified by the deep valley entering the southwest corner of Shelby County. These buried valleys are overlain by end moraines and ground moraine and cannot be distinguished at the surface. Such valleys usually lack modern streams or have only intermittent streams overlying them. The aquifer consists of thinner, less continuous lenses of sand and gravel interbedded in thick sequences of till or fine lacustrine sediments. Yields are commonly less than 30 gpm. Soils are typically clay loams. Recharge is moderate to low.

The GWPP index values for the hydrogeologic setting Buried Valleys range from 83 to 171 with the total number of GWPP index calculations equaling 80.

Setting	Depth to Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pest Rating
7D1	45	4-7	Sand and gravel	Clay Loam	0-2	Sand and gravel w/ silt and clay	300-700	140	160
7D2	35	4-7	Sand and gravel	Clay Loam	0-2	Till	300-700	125	146
7D3	45	4-7	Sand and gravel	Clay Loam	0-2	Till	300-700	135	156
7D4	25	4-7	Sand and gravel	Clay Loam	0-2	Till	300-700	115	136
7D5	25	4-7	Sand and gravel	Clay Loam	2-6	Till	300-700	114	133
7D6	25	4-7	Sand and gravel	Shrinking and/or Aggregated Clay	0-2	Till	300-700	123	156
7D7	25	4-7	Sand and gravel	Clay Loam	0-2	Sand and gravel w/ silt and clay	300-700	120	140

Setting	Depth to Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pest Rating
7D8	35	4-7	Sand and gravel	Clay Loam	0-2	Sand and gravel w/ silt and clay	300-700	130	150
7D9	45	4-7	Sand and gravel	Shrinking and/or Aggregated Clay	0-2	Till	300-700	143	176
7D10	45	4-7	Sand and gravel	Clay Loam	0-2	Sand and gravel w/ silt and clay	300-700	140	160
7D11	35	4-7	Sand and gravel	Shrinking and/or Aggregated Clay	0-2	Till	300-700	133	166
7D12	35	4-7	Sand and gravel	Clay Loam	2-6	Sand and gravel w/ silt and clay	300-700	129	147
7D13	45	4-7	Sand and gravel	Silty Loam	0-2	Silt/clay	300-700	142	165
7D14	35	4-7	Sand and gravel	Sandy Loam	0-2	Sand and gravel w/ silt and clay	300-700	136	165
7D15	45	4-7	Sand and gravel	Shrinking and/or Aggregated Clay	0-2	Sand and gravel w/ silt and clay	300-700	148	180
7D16	35	4-7	Sand and gravel	Sandy Loam	2-6	Sand and gravel w/ silt and clay	300-700	135	162
7D17	25	4-7	Sand and gravel	Sandy Loam	6-12	Sand and gravel w/ silt and clay	300-700	121	140
7D18	25	4-7	Sand and gravel	Clay Loam	2-6	Sand and gravel w/ silt and clay	300-700	119	137
7D19	35	4-7	Sand and gravel	Peat	0-2	Sand and gravel w/ silt and clay	300-700	140	175
7D20	15	2-4	Sand and gravel	Clay Loam	2-6	Till	300-700	87	107
7D21	15	2-4	Sand and gravel	Clay Loam	6-12	Till	300-700	83	95
7D22	15	2-4	Sand and gravel	Clay Loam	2-6	Till	300-700	90	110
7D23	25	4-7	Sand and gravel	Clay Loam	0-2	Till	300-700	118	139
7D24	25	4-7	Sand and gravel	Clay Loam	2-6	Sand and gravel w/ silt and clay	300-700	122	140
7D25	25	4-7	Sand and gravel	Clay Loam	0-2	Sand and gravel w/ silt and clay	300-700	123	143
7D26	35	4-7	Sand and gravel	Clay Loam	0-2	Till	300-700	128	149
7D27	25	4-7	Sand and gravel	Sandy Loam	6-12	Sand and gravel w/ silt and clay	300-700	124	143
7D28	35	4-7	Sand and gravel	Clay Loam	0-2	Sand and gravel w/ silt and clay	300-700	133	153
7D29	25	4-7	Sand and gravel	Clay Loam	6-12	Sand and gravel w/ silt and clay	300-700	115	125
7D30	35	7-10	Sand and gravel	Sandy Loam	0-2	Sand and gravel w/ silt and clay	300-700	152	180
7D31	45	7-10	Sand and gravel	Shrinking and/or Aggregated Clay	0-2	Sand and gravel w/ silt and clay	300-700	164	195
7D32	45	4-7	Sand and gravel	Clay Loam	0-2	Till	300-700	138	159
7D33	35	4-7	Sand and gravel	Clay Loam	2-6	Sand and gravel w/ silt and clay	300-700	132	150
7D34	45	4-7	Sand and gravel	Clay Loam	0-2	Sand and gravel w/ silt and clay	300-700	143	163
7D35	35	4-7	Sand and gravel	Clay Loam	2-6	Till	300-700	127	146
7D36	25	4-7	Sand and gravel	Clay Loam	2-6	Till	300-700	117	136
7D37	25	4-7	Sand and gravel	Clay Loam	6-12	Till	300-700	113	124
7D38	25	4-7	Sand and gravel	Clay Loam	12-18	Till	300-700	111	118
7D39	45	4-7	Sand and gravel	Silty Loam	0-2	Sand and gravel w/ silt and clay	300-700	145	168
7D40	45	4-7	Sand and gravel	Shrinking and/or Aggregated Clay	0-2	Till	300-700	146	179
7D41	15	2-4	Sand and gravel	Clay Loam	0-2	Till	300-700	91	113
7D42	15	2-4	Sand and gravel	Clay Loam	2-6	Till	700-1000	96	114
7D43	15	2-4	Sand and gravel	Clay Loam	0-2	Till	700-1000	97	117

Setting	Depth to Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pest Rating
7D44	35	4-7	Sand and gravel	Clay Loam	0-2	Till	100-300	119	142
7D45	35	4-7	Sand and gravel	Clay Loam	2-6	Till	100-300	118	139
7D46	45	7-10	Sand and gravel	Silty Loam	0-2	Sand and gravel w/ silt and clay	700-1000	164	184
7D47	35	4-7	Sand and gravel	Shrinking and/or Aggregated Clay	0-2	Till	300-700	136	169
7D48	35	4-7	Sand and gravel	Peat	0-2	Till	300-700	138	174
7D49	35	4-7	Sand and gravel	Silty Loam	0-2	Silt/clay	300-700	130	154
7D50	35	7-10	Sand and gravel	Sandy Loam	0-2	Sand and gravel w/ silt and clay	700-1000	158	184
7D51	25	4-7	Sand and gravel	Clay Loam	6-12	Till	300-700	110	121
7D52	35	4-7	Sand and gravel	Silty Loam	0-2	Silt/clay	300-700	127	151
7D53	35	4-7	Sand and gravel	Silty Loam	0-2	Silt/clay	300-700	130	154
7D54	45	4-7	Sand and gravel	Silty Loam	0-2	Silt/clay	300-700	140	164
7D55	15	2-4	Sand and gravel	Clay Loam	0-2	Till	300-700	88	110
7D56	35	4-7	Sand and gravel	Sandy Loam	0-2	Sand and gravel w/ silt and clay	300-700	139	168
7D57	10	2-4	Sand and gravel	Clay Loam	0-2	Till	300-700	83	105
7D58	45	7-10	Sand and gravel	Silty Loam	0-2	Sand and gravel w/ silt and clay	300-700	158	180
7D59	45	7-10	Sand and gravel	Sandy Loam	0-2	Sand and gravel w/ silt and clay	300-700	162	190
7D60	25	4-7	Sand and gravel	Clay Loam	12-18	Till	300-700	108	115
7D61	35	4-7	Sand and gravel	Sandy Loam	0-2	Sand and gravel w/ silt and clay	700-1000	145	172
7D62	45	7-10	Sand and gravel	Sandy Loam	0-2	Sand and gravel w/ silt and clay	700-1000	168	194
7D63	35	4-7	Sand and gravel	Clay Loam	6-12	Sand and gravel w/ silt and clay	700-1000	134	142
7D64	35	4-7	Sand and gravel	Clay Loam	2-6	Till	300-700	124	143
7D65	45	7-10	Sand and gravel	Silty Loam	0-2	Sand and gravel w/ silt and clay	300-700	153	176
7D66	35	7-10	Sand and gravel	Sandy Loam	0-2	Sand and gravel w/ silt and clay	700-1000	161	187
7D67	45	7-10	Sand and gravel	Sandy Loam	0-2	Sand and gravel w/ silt and clay	700-1000	171	197
7D68	35	4-7	Sand and gravel	Silty Loam	0-2	Sand and gravel w/ silt and clay	300-700	135	158
7D69	25	4-7	Sand and gravel	Sandy Loam	0-2	Till	300-700	121	151
7D70	25	4-7	Sand and gravel	Sandy Loam	2-6	Sand and gravel w/ silt and clay	300-700	125	152
7D71	25	4-7	Sand and gravel	Sandy Loam	6-12	Till	300-700	119	139
7D72	35	4-7	Sand and gravel	Clay Loam	12-18	Till	300-700	121	128
7D73	35	4-7	Sand and gravel	Clay Loam	12-18	Till	300-700	118	125
7D74	35	4-7	Sand and gravel	Clay Loam	12-18	Sand and gravel w/ silt and clay	300-700	123	129
7D75	50	4-7	Sand and gravel	Clay Loam	2-6	Sand and gravel w/ silt and clay	300-700	144	162
7D76	45	4-7	Sand and gravel	Silty Loam	0-2	Sand and gravel w/ silt and clay	700-1000	156	176
7D77	45	7-10	Sand and gravel	Silty Loam	0-2	Sand and gravel w/ silt and clay	300-700	150	173
7D78	45	4-7	Sand and gravel	Sandy Loam	0-2	Sand and gravel w/ silt and clay	300-700	146	175
7D79	45	4-7	Sand and gravel	Clay Loam	0-2	Sand and gravel w/ silt and clay	100-300	131	153
7D80	35	4-7	Sand and gravel	Clay Loam	6-12	Sand and gravel w/ silt and clay	100-300	116	128

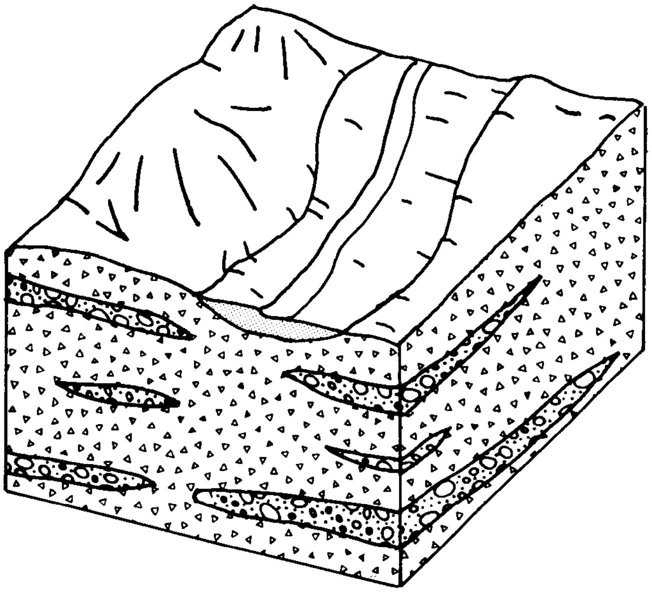


7Ec Alluvium Over Sedimentary Rock

This hydrogeologic setting was found primarily in central Shelby County. This hydrogeologic setting is very similar to the 7Ac Glacial Till Over Limestone setting except that the area contains a modern stream and floodplain. This hydrogeologic setting is characterized by low relief with thin to moderate thicknesses of modern, stream-deposited alluvium. The alluvium is composed of silt, clay, fine sand, and minor gravel. Depth to water is shallow and the stream is in direct hydraulic connection with the underlying alluvium. The aquifer is the underlying, fractured Silurian limestones and dolomites. Yields for domestic wells range from 20 to 40 gpm and large diameter wells are capable of producing yields exceeding 100 gpm. Soils are typically silt loams. Recharge is moderately high due to the shallow depth to water, flat topography, and the moderately permeable nature of the alluvium.

The GWPP index values for the hydrogeologic setting Alluvium Over Sedimentary Rocks range from 128 to 159 with the total number of GWPP index calculations equaling 7.

Setting	Depth to Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pest Rating
7Ec1	45	4-7	Massive limestone	Shrinking and/or Aggregated Clay	0-2	Silt/clay	300-700	146	179
7Ec2	45	4-7	Solution limestone	Clay Loam	0-2	Silt/clay	300-700	141	162
7Ec3	45	7-10	Solution limestone	Peat	0-2	Silt/clay	300-700	159	195
7Ec4	35	4-7	Massive limestone	Clay Loam	0-2	Silt/clay	300-700	128	149
7Ec5	35	4-7	Massive limestone	Silty Loam	0-2	Silt/clay	300-700	130	154
7Ec6	35	4-7	Solution limestone	Clay Loam	0-2	Silt/clay	300-700	131	152
7Ec7	35	4-7	Solution limestone	Silty Loam	0-2	Silt/clay	300-700	133	157

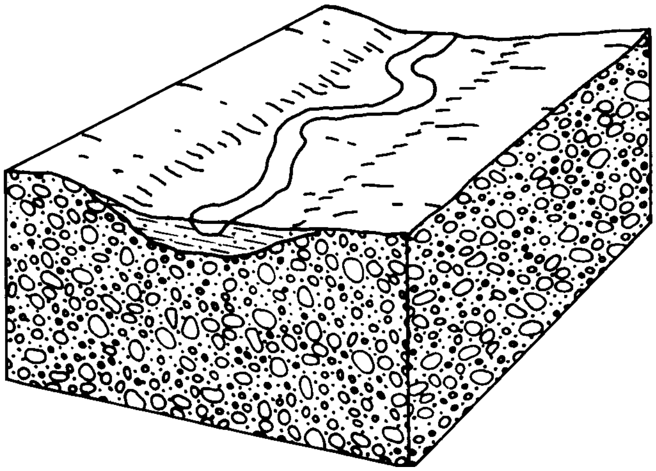


7Ed River Alluvium Over Till

This hydrogeologic setting is composed of flat-lying floodplains and stream terraces comprised of 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 stream may or may not be in hydraulic connection with the underlying sand and gravel deposits which constitute the aquifer. The surficial, silty alluvium is typically more permeable than the surrounding till. The alluvium is too thin to be the aquifer. Soils are typically silt loams. Yields typically average from 10 to 25 gpm. Depth to water is usually less than 20 feet. Water percolating through the alluvium may serve as an avenue of recharge to the underlying lenses of sand and gravel. Recharge is moderate due to the shallow depth to water, the flat topography, and the relatively low permeability of the glacial till.

GWPP index values for the hydrogeologic setting Alluvium Over Glacial Till range from 127 to 161 with the total number of GWPP calculations equaling 13.

Setting	Depth to Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pest Rating
7Ed1	50	4-7	Sand & gravel	Silty Loam	0-2	Sand & gravel w/ silt & clay	700-1000	161	181
7Ed2	50	4-7	Sand & gravel	Clay Loam	0-2	Silt/clay	300-700	140	161
7Ed3	45	4-7	Sand & gravel	Shrinking & /or Aggregated Clay	0-2	Till	300-700	143	176
7Ed4	35	4-7	Sand & gravel	Clay Loam	0-2	Till	300-700	128	149
7Ed5	35	4-7	Sand & gravel	Silty Loam	0-2	Silt/clay	300-700	127	151
7Ed6	45	4-7	Sand & gravel	Silty Loam	0-2	Silt/clay	300-700	137	161
7Ed7	45	4-7	Sand & gravel	Silty Loam	0-2	Sand & gravel w/ silt & clay	300-700	142	165
7Ed8	35	4-7	Sand & gravel	Silty Loam	0-2	Silt/clay	300-700	130	154
7Ed9	35	4-7	Sand & gravel	Silty Loam	0-2	Sand & gravel w/ silt & clay	300-700	135	158
7Ed10	45	7-10	Sand & gravel	Sandy Loam	0-2	Sand & gravel w/ silt & clay	300-700	157	186
7Ed11	45	7-10	Sand & gravel	Silty Loam	0-2	Sand & gravel w/ silt & clay	300-700	153	176
7Ed12	45	4-7	Sand & gravel	Shrinking &/or Aggregated Clay	0-2	Sand & gravel w/ silt & clay	300-700	151	183
7Ed13	45	4-7	Sand & gravel	Silty Loam	0-2	Sand & gravel w/ silt & clay	700-1000	151	172



7Ee Alluvium Over Outwash

This hydrogeologic setting is limited to portions of Turtle Creek and lower Loramie Creek that do not have an adequate thickness of drift to be considered buried valleys. The setting is characterized by low relief floodplains and low-lying terraces with thin to moderate thicknesses of modern alluvium overlying outwash. The alluvium is composed of silt, clay, and fine sand. Soils are typically silt loams or sandy loams. The depth to water is shallow, averaging less than 20 feet. Streams are typically in hydraulic connection with the underlying permeable sand and gravel outwash. The outwash consists of coarse, moderately-well sorted, stratified sand and gravel. Yields up to 500 gpm may be possible from large-diameter, properly developed wells. Recharge is moderately high due to the permeable soils and vadose zone materials, the flat topography, and the shallow depth to water.

The GWPP index values for the hydrogeologic setting 7Ee Alluvium Over Outwash range from 135 to 164 with the total number of GWPP index calculations equaling 5.

Setting	Depth to Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pest Rating
7Ee1	45	7-10	Sand and gravel	Sandy Loam	0-2	Sand and gravel w/ silt and clay	300-700	162	190
7Ee2	45	7-10	Sand and gravel	Silty Loam	0-2	Sand and gravel w/ silt and clay	700-1000	164	184
7Ee3	35	7-10	Sand and gravel	Sandy Loam	0-2	Sand and gravel w/ silt and clay	700-1000	158	184
7Ee4	35	4-7	Sand and gravel	Silty Loam	0-2	Sand and gravel w/ silt and clay	300-700	135	158
7Ee5	35	4-7	Sand and gravel	Sandy Loam	0-2	Sand and gravel w/ silt and clay	700-1000	145	172

ERRATA SHEET

SHELBY COUNTY
Ground Water Pollution Potential No. 46

Changes on Map:

The thin, light-blue unlabeled polygon on the extreme eastern edge of map, just north of the Miami River should be labeled 7Af2 (115). This is in far eastern Salem Township.

The thin, unlabeled light-green polygon along Mosquito Creek near the junction of Leatherwood Creek should be labeled 7Ed10 (157). This polygon lies on the border between Perry and Green Townships.

A small irregular-shaped light-blue unlabeled polygon lies just northeast of the junction between Counts Run and the Miami River should be labeled 7D36 (117). This is in west-central Salem Township.