GROUND WATER POLLUTION POTENTIAL OF MUSKINGUM COUNTY, OHIO

BY

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ABSTRACT

A ground water pollution potential map of Muskingum 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 Muskingum County resulted in a map with symbols and colors that illustrate areas of varying ground water contamination vulnerability. Eleven hydrogeologic settings were identified in Muskingum County with computed ground water pollution potential indexes ranging from 63 to 190.

Muskingum County lies within the Nonglaciated Central hydrogeologic setting. The extreme western edge of Hopewell Township is within the Glaciated Central hydrogeologic setting. The buried valley underlying portions of the present Muskingum River basin contains sand and gravel outwash that is capable of yielding up to 500 gallons per minute (gpm) from properly designed, large diameter wells. Other areas of the Muskingum River and Licking River containing less continuous, thinner outwash deposits have yields varying from 100 to 500 gpm down to 25 to 100 gpm. Wells completed in thin sand and gravel lenses interbedded in thicker sequences of finer-grained alluvial and lacustrine deposits yield an average of 5 to 25 gpm. Such deposits are common to the many tributaries northwest of Zanesville. Smaller tributaries contain only thin, fine-grained alluvial/lacustrine deposits commonly yielding less than 5 gpm.

Interbedded sandstones and shales of the Mississippian Logan Formation and interbedded sandstones, shales, siltstones, and thin coals of the Pennsylvanian Pottsville Group have yields averaging from 10 to 25 gpm. The Mississippian Maxville Limestone has average yields of 5 to 10 gpm. Dirty sandstones, shales, thin limestones, coals, and claystones of the Pennsylvanian Allegheny Group have yields in the 5 to 10 gpm range. Sandstones, claystones, and limestones of the Pennsylvanian Conemaugh Group and Monongahela Group are poor aquifers and yields are commonly less than 5 gpm.

The ground water pollution potential mapping program optimizes the use of existing data to rank areas with respect to relative vulnerability to contamination. The ground water pollution potential map of Muskingum 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; 12,400 of these wells exist in Muskingum County.

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

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

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

APPLICATIONS OF POLLUTION POTENTIAL MAPS

The pollution potential mapping program offers a wide variety of applications in many counties. The ground water pollution potential map of Muskingum County has been prepared to assist planners, managers, and state and local officials in evaluating the relative vulnerability of areas to ground water contamination from various sources of pollution. This information can be used to help direct resources and land use activities to appropriate areas, or to assist in protection, monitoring, and clean-up efforts.

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

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

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

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

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

SUMMARY OF THE DRASTIC MAPPING PROCESS

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

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

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

Hydrogeologic Settings and Factors

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

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

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

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

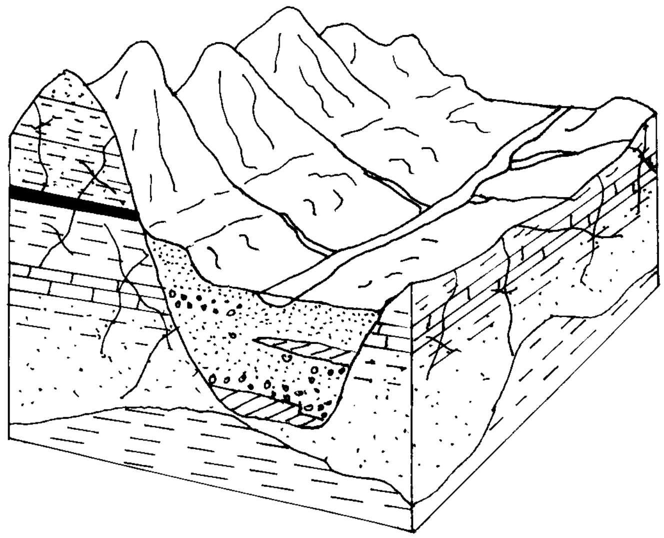
These factors incorporate concepts and mechanisms such as attenuation, retardation, and time or distance of travel of a contaminant with respect to the physical characteristics of the hydrogeologic setting. Broad consideration of these factors and mechanisms coupled with existing conditions in a setting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

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

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

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

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



<u>7D Buried Valley</u>

This hydrogeologic setting is widespread throughout Muskingum County. All of the major trunk streams and some of the modern tributaries overlie buried valley deposits. There are also former drainage ways overlying buried valleys that lack modern streams, notably the broad valley extending westward from Frazeysburg. Broad, flat-lying floodplains and gently sloping terraces characterize the setting. Depths to water are variable; they are typically less than 30 feet in valleys containing modern streams and are commonly over 45 feet in valleys lacking modern streams. Aquifers are composed of variable thicknesses of sand and gravel interbedded with finer-grained alluvium, till, and lacustrine deposits. The modern streams may be in direct hydraulic connection with the underlying aquifer. Yields up to 500 gpm have been reported for some of the coarser, thicker, more continuous sand and gravel outwash in portions of the Muskingum River Valley and Licking River Valley. Yields up to 100 gpm are developed in remaining portions of the Muskingum River Valley and Licking River Valley. Some valleys, including Wills Creek and the tributary valleys east of the Licking River, contain thin lenses of sand and gravel interbedded with much thicker sequences of finer-grained alluvial and lacustrine deposits. Soils on terraces are typically sandy loams derived from outwash; soils on floodplains are silt loams derived from modern alluvium. Recharge is typically relatively high due to the flat-lying topography, shallow depth to water, and the high permeability of the soils, vadose zone materials, and aquifer for buried valleys with modern overlying streams. Recharge tends to be less in valleys lacking modern streams, having greater depths to water, and less permeable soils and vadose media.

GWPP index values for the hydrogeologic setting of Buried Valley range from 111 to 190, with the total number of GWPP index calculations equaling 49.

Figure 1. Format and description of the hydrogeologic setting - 7D Buried Valley.

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

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

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

Weighting and Rating System

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

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

Pesticide DRASTIC

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

Table 1. Assigned weights for DRASTIC features

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

Table 2. Ranges and ratings for depth to water

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

Table 3. Ranges and ratings for net recharge

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

Table 4. Ranges and ratings for aquifer media

Aquifer Media		
Range	**Rating**	**Typical Rating**
Shale	1-3	2
Glacial Till	4-6	5
Sandstone	4-9	6
Limestone	4-9	6
Sand and Gravel	4-9	8
Interbedded Ss/Sh/Ls/Coal	2-10	9
Karst Limestone	9-10	10
Weight: 3	Pesticide Weight: 3	

Table 5. Ranges and ratings for soil media

Soil Media	
Range	**Rating**
Thin or Absent	10
Gravel	10
Sand	9
Peat	8
Shrink/Swell Clay	7
Sandy Loam	6
Loam	5
Silty Loam	4
Clay Loam	3
Muck	2
Clay	1
Weight: 2	Pesticide Weight: 5

Table 6. Ranges and ratings for topography

Topography (percent slope)	
Range	**Rating**
0-2	10
2-6	9
6-12	5
12-18	3
18+	1
Weight: 1	Pesticide Weight: 3

Table 7. Ranges and ratings for impact of the vadose zone media

Impact of the Vadose Zone Media		
Range	**Rating**	**Typical Rating**
Confining Layer	1	1
Silt/Clay	2-6	3
Shale	2-5	3
Limestone	2-7	6
Sandstone	4-8	6
Interbedded Ss/Sh/Ls/Coal	4-8	6
Sand and Gravel with Silt and Clay	4-8	6
Glacial Till	2-6	4
Sand and Gravel	6-9	8
Karst Limestone	8-10	10
Weight: 5	Pesticide Weight: 4	

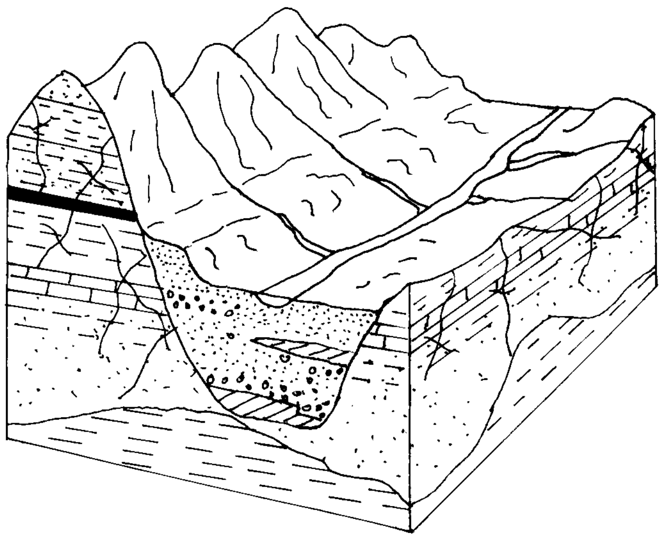
Table 8. Ranges and ratings for hydraulic conductivity

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

Integration of Hydrogeologic Settings and DRASTIC Factors

Figure 2 illustrates the hydrogeologic setting 7D1, Buried Valley, identified in mapping Muskingum 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 155. 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 Muskingum County produces settings with a wide range of vulnerability to ground water contamination. Calculated pollution potential indexes for the 11 settings identified in the county range from 63 to 190.

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 Muskingum 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 Muskingum County is included with this report.



SETTING 7D1		GENERAL		
FEATURE	**RANGE**	**WEIGHT**	**RATING**	**NUMBER**
Depth to Water	5-15	5	9	45
Net Recharge	7-10	4	8	32
Aquifer Media	Sand & Gravel	3	6	18
Soil Media	Silty Loam	2	4	8
Topography	0-2%	1	10	10
Impact of Vadose Zone	Sand & Gravel w/Silt & Clay	5	6	30
Hydraulic Conductivity	300-700	3	4	12
		DRASTIC	INDEX	155

Figure 2. Description of the hydrogeologic setting - 7D1 Buried Valley.

INTERPRETATION AND USE OF GROUND WATER POLLUTION POTENTIAL MAPS

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

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

7D1 - defines the hydrogeologic region and setting
155 - defines the relative pollution potential

Here the first number (**7**) refers to the major hydrogeologic region and the upper case letters (**D**) 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 (**155**) is the calculated pollution potential index for this unique setting. The charts for each setting provide a reference to show how the pollution potential index was derived.

The maps are color-coded using ranges depicted on the map legend. The color codes used are part of a national color-coding scheme developed to assist the user in gaining a general insight into the vulnerability of the ground water in the area. The color codes were chosen to represent the colors of the spectrum, with warm colors (red, orange, and yellow) representing areas of higher vulnerability (higher pollution potential indexes), and cool colors (greens, blues, and violet) representing areas of lower vulnerability to contamination. The maps also delineate large man-made and natural features such as lakes, landfills, quarries, and strip mines, but these areas are not rated and therefore not color-coded.

GENERAL INFORMATION ABOUT MUSKINGUM COUNTY

Demographics

Muskingum County occupies approximately 651 square miles in southeastern Ohio (Figure 3). Muskingum County is bounded to the northeast by Guernsey County, to the southeast by Noble County, to the south by Morgan County, to the southwest by Perry County, to the northwest by Licking County, and to the north by Coshocton County.

The approximate population of Muskingum County, based upon 1998 estimates, is 84,470 (Department of Development, Ohio County Profiles, 1999). Zanesville is the largest community and the county seat. Woodland and pasture are the major land uses in the county. There are numerous recreational/wildlife areas throughout the county. Agriculture is also an important land use. Strip mining has historically been an important land use in the central and eastern portion of the county. More specific information on land usage can be obtained from the Ohio Department of Natural Resources, Division of Real Estate and Land Management (REALM), Resource Analysis Program (formerly OCAP).

Climate

The *Hydrologic Atlas for Ohio* (Harstine, 1991) reports an average annual temperature of approximately 52 degrees Fahrenheit for Muskingum County. The average temperatures increase slightly towards the south. Harstine (1991) shows that precipitation averages 39 inches per year for the majority of the county, but declines in the southern end of the county. The mean annual precipitation for Zanesville is 39.42 inches per year based upon a thirty-year (1961-1990) period (Owenby and Ezell, 1992). The mean annual temperature at Zanesville for the same thirty-year period is 51.3 degrees Fahrenheit (Owenby and Ezell, 1992).

Physiography and Topography

Muskingum County lies almost entirely within the Unglaciated Allegheny Plateau section of the Appalachian Plateau Province (Frost, 1931 and Fenneman, 1938). The extreme western edge of Hopewell Township has been glaciated during the Wisconsinan ice-advance and is part of the Glaciated Allegheny Plateau section. Relatively high relief and rugged topography, featuring narrow ridges, steep slopes, and a high degree of stream dissection characterize the county. Floodplains of the Muskingum River and its major tributaries are relatively broad and flat lying.

Figure 3. Location of Muskingum County, Ohio.

Modern Drainage

The Muskingum River and its tributaries drain Muskingum County. The main trunk of the Muskingum River drains the central portion of the county. Important western tributaries include Mill Fork, Wakatomika Creek, Licking River, Jonathan Creek, and Moxahala Creek. Salt Creek is the major tributary draining the southeastern corner of the county. Wills Creek and its tributaries drain the eastern edge of the county. Wills Creek flows to the north through central Guernsey County and then turns westward, emptying into the Muskingum River at the Muskingum County–Coshocton County boundary. Tributaries of Wills Creek with their headwaters in eastern Muskingum County include Buffalo Creek, Crooked Creek, and White Eyes Creek.

Pre- and Inter-Glacial Drainage Changes

Muskingum County lies almost entirely beyond the glacial boundary; however, the drainage patterns of the county changed greatly as a result of the multiple glaciations. The drainage changes are complex and not yet fully understood. More research and data are necessary in both Muskingum County and adjacent counties. Particularly, well log data for deeper wells that penetrate the entire drift thickness would be helpful in making interpretations.

Prior to glaciation, the Teays River System drained southeastern Ohio (Figure 4). The Cambridge River and its tributaries drained Muskingum County (Stout et al., 1943 and Stout, 1918). It cut across the northwestern corner of the county, flowing in the broad valley that underlies the Frazeysburg and Dresden region. The Cambridge River flowed westward, emptying into the Groveport River near present day Newark. The Groveport River was an important eastern tributary of Teays River.

A tributary of the Cambridge River was Putnam Creek. The headwaters for Putnam Creek approximately followed the course of Moxahala Creek in Muskingum County, flowing north towards Zanesville and then curved northwestward, roughly following the course of modern Licking River. Sonora Creek was a northerly flowing tributary of Putnam Creek. Sonora Creek roughly followed the course of the present Muskingum River and emptied into Putnam Creek near Zanesville. There was a major drainage divide in northern Morgan County nearby present-day Eagleport that blocked any drainage towards the south (Norling, 1958). The divide consisted of a resistant bedrock ridge or col; north of this col, drainage was to the northwest.

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 River 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 these new streams was believed to be relatively rapid and, in many places, the new channels were cut over 100 feet deeper than the previous Teays River System valleys. The new drainage system (Figure 5) is referred to as the Deep Stage due to

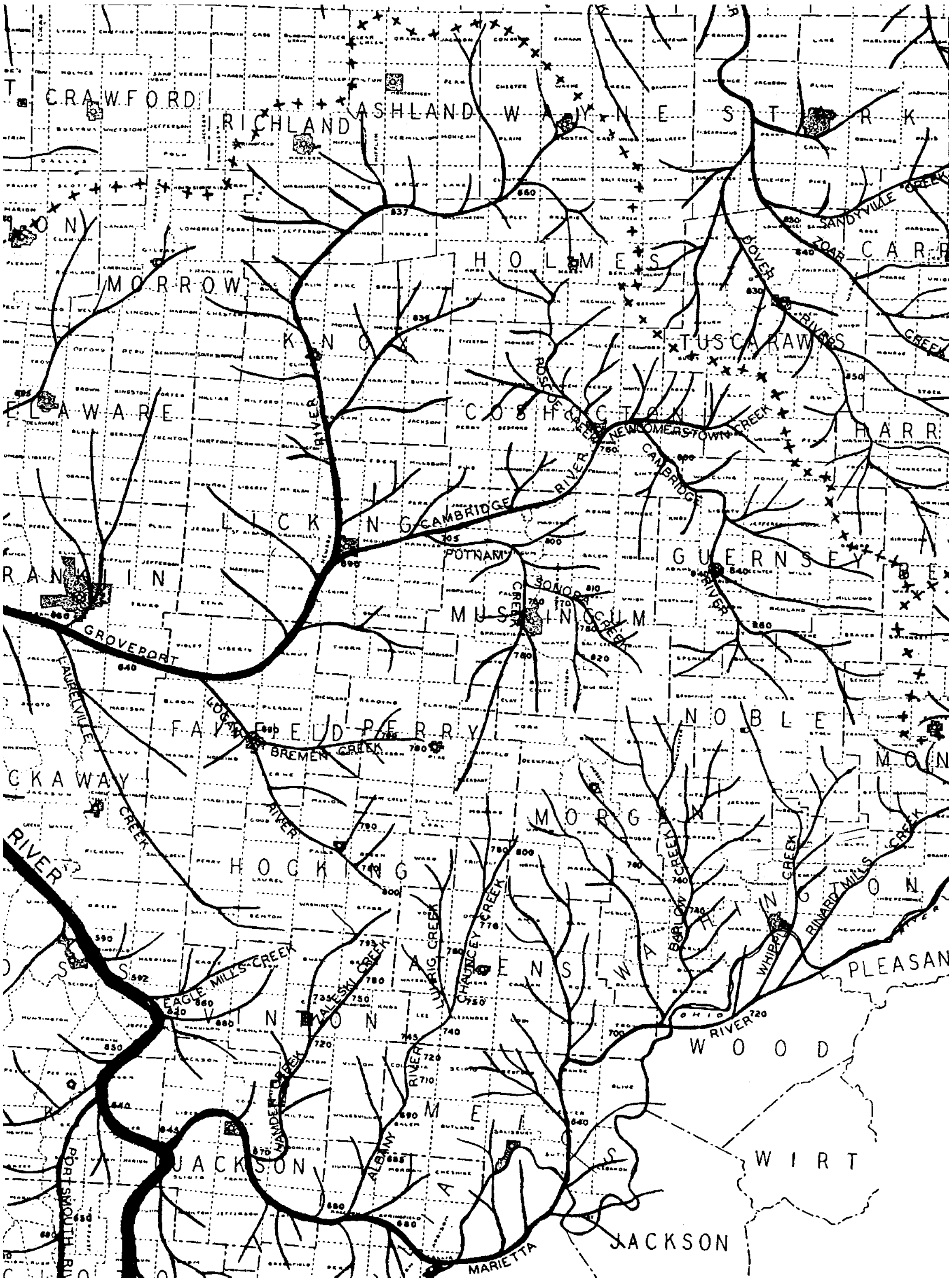


Figure 4. Pre-glacial Teays Stage drainage (after Stout et al., 1943).

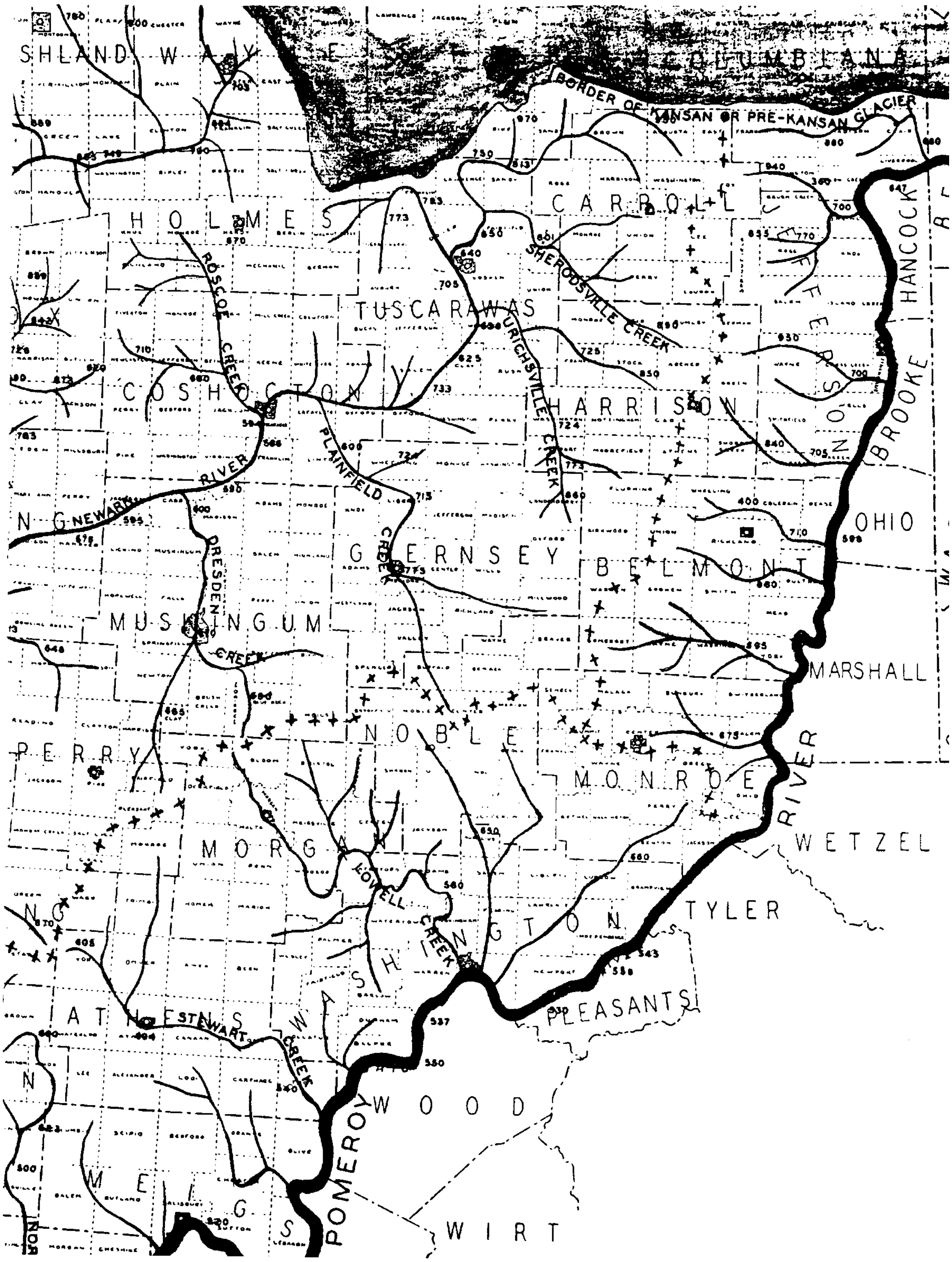


Figure 5. Deep Stage drainage (after Stout et al., 1943).

this increased downcutting. A new trunk stream referred to as the Newark River down-cut and its headwaters eroded eastward, eventually extending to the city of Coshocton. In Muskingum County, the Newark River deepened the channel previously occupied by the Cambridge River. Dresden Creek, a northerly flowing tributary that closely followed the course of the present Muskingum River, predominantly drained Muskingum County. The divide (col) in northern Morgan County was still not breached at this time. During this time, the ancestral Ohio River became established.

The Illinoian ice advance brought further changes to the drainage systems (Figure 6). Opinions as to the nature of drainage changes as a result of the advancing Illinoian ice front differ. Stout et al. (1943) determined that Illinoian ice either did not advance into northeastern Ohio, or at least advanced at a different time then in western Ohio. As the Illinoian ice sheet advanced eastward from central Ohio, the Newark River was blocked in Licking County. Stout et al. (1943) suggested that the waters of the blocked drainage rose and eventually were diverted to the north; basically re-occupying the channel of the former Dover River. At this time, drainage to the north was possible, as advancing Illinoian ice did not block this area. Stout et al. (1943) referred to this northerly flowing trunk stream as the Massillon River. Headwaters for Ashcraft Creek, a northerly-flowing tributary to the Massillon River, drained most of Muskingum County.

Lamborn (1956) and DeLong and White (1961) proposed that Illinoian ice did advance into northeastern Ohio and blocked drainage northward. They proposed that drainage was still primarily to the southwest through the Newark River. Ice-blockage between the towns of Newark and Hanover caused the Newark River to back-up and pond in the trunk valley and tributaries though much of eastern Licking County, Muskingum County, Coshocton County and Tuscarawas County. Abundant fine-grained sediments were deposited in these ponded valleys. Eventually, divides were breached, notably at the Black Hand Gorge in eastern Licking County and new drainage ways were established along the Licking River and Muskingum River (Carney, 1907; Dove, 1960; and Bork and Malcuit, 1987). It was at this time the ancestral trunk stream abandoned the channel from Dresden-Frazeysburg-Hanover (Dove, 1960).

The massive volumes of meltwater produced during the Wisconsinan (most recent) ice advance eventually breached the col near Eagleport (Norling, 1958). This led to the establishment of the modern Muskingum River System (Stout et al., 1943 and Norling, 1958). The Muskingum River Valley contains a variety of coarse outwash, silty alluvial and finer lacustrine (lake) sediments which were deposited over time. Ancestral stream channels filled with glacial/alluvial sediments are referred to as buried valleys.

Glacial Geology

During the Illinoian ice advance, ice entered the western part of Hopewell Township. The ice deposited a moderately sandy to clayey, highly weathered till which thinly mantled the local uplands (Goldthwait et al., 1961; Forsyth, 1966, and Pavey et al., 1999).

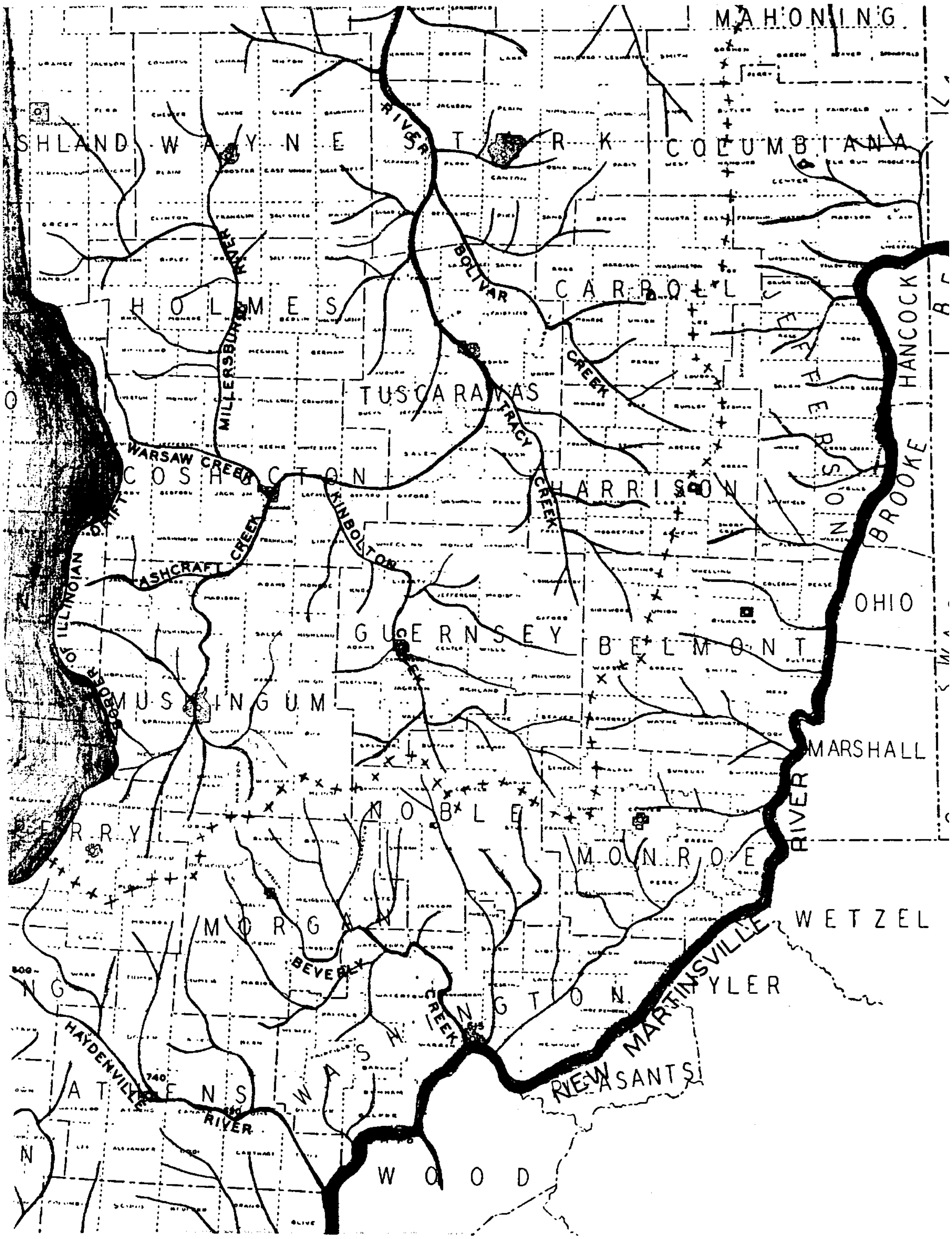


Figure 6. Illinoian-age drainage (after Stout et al., 1943).

The majority of the glacially-related deposits are limited to the ancestral stream channels (White et al., 1961, Pavey et al., 1999, Walker, 1992, and ODNR, Div. of Water, Open File Glacial State Aquifer Map). Ancestral stream channels filled with glacial/alluvial sediments are referred to as buried valleys. The buried valleys are filled with differing sequences of coarse sand and gravel outwash, finer-grained lacustrine and modern, silty alluvial or floodplain deposits. These deposits vary with the energy level of the streams at that time. Streams leading away from melting glaciers are high energy and deposit coarser outwash. Outwash contains interbedded layers of sand and gravel deposited by a braided stream system. Streams that are blocked by ice or by thick channel deposits tend to be ponded and fill with finer-grained sediments. Modern tributaries, which lead into streams overlying the buried valleys, tend to contain variable thicknesses of sand, gravel, and silty alluvium.

Muskingum County also has many deposits of loess of appreciable thickness, particularly in the Zanesville area (Steiger, 1996). Loess is a deposit formed by wind-blown silt. Loess is derived from the wind picking up fine silt-sized (to very fine-grained sand) particles covering the floodplains of the wide outwash or lacustrine valley floors. Loess is commonly found capping bedrock uplands and higher stream terraces to the east (upwind) of major river valleys. Thicknesses of loess exceeding 15 feet have been noted for Muskingum County. In some of the lower to middle elevation terraces, it may be difficult to differentiate whether the silty deposit is slack water lacustrine, loess, loess deposited in shallow standing water, or any combination of these (Larry Tornes, ODNR, Div. of Soil and Water, personal communication, 2001). Loess is particularly important to the development of soils in these upland and terrace areas.

Bedrock Geology

Bedrock exposed at the surface in Muskingum County belongs to the Mississippian and Pennsylvanian Systems. Table 9 summarizes the bedrock stratigraphy found in Muskingum County. Stout (1918) gives a thorough review of the bedrock stratigraphy of Muskingum County. The ODNR, Division of Geological Survey, has Open-File Reconnaissance Bedrock Geological Maps done on a 1:24,000 USGS topographic map base available for the entire county. The oldest rocks exposed in Muskingum County are part of the Mississippian Logan Formation and are found along the northwestern margin of the county. The Mississippian Maxville Limestone is exposed in the southwestern corner of the county (Lamborn, 1951). The oldest Pennsylvanian rocks are interbedded sandstones, shales, siltstones, and thin coals of the Pottsville Group. These rocks are limited to the western margin of the county. Rocks of the Allegheny Group include interbedded dirty sandstones, shales, siltstones, and thin limestones and coals, and are found primarily in the western third of the county. Rocks of the Conemaugh Group are exposed in much of the central and eastern part of the county. These rocks include interbedded dirty, micaceous sandstones, shales, siltstones, thin, fine-grained limestones, and minor coals. Higher in the section, the rocks tend to include more fine-grained mudstones and claystones (Collins, 1979). Rocks of the Monongahela Group are found mostly in southeastern Muskingum County. These rocks include interbedded dirty sandstones, shales, minor limestones, and some important coal beds, particularly in the northern part of the county.

Table 9. Bedrock stratigraphy of Muskingum County, Ohio

System	Group/Formation (Symbol)	Lithologic Description
Pennsylvanian	Pennsylvanian Undivided, i.e. Conemaugh, Monongahela Fms. (Pu)	Interbedded dirty sandstones, shales, and siltstones with thin coal, limestones, and clay. Poor aquifer, yields less than 5 gallons per minute. Found in eastern third of Muskingum County.
	Allegheny Group Pottsville Group (Pap)	Interbedded gray to black sandstones, shale, and siltstone with thin limestone, coal, clay, and flint. Commonly found in central, northern, and western Muskingum County. Poor aquifer, yields less than 5 gallons per minute. Yields up to 25 gpm in northwestern Muskingum County.
Mississippian	Mississippian Undivided Significant formations include the Maxville Limestone, Logan Formation, and the Cuyahoga Formation (Mu)	The Maxville Limestone is gray, massive to nodular, and fossiliferous. The Logan Formation consists of interbedded sandstone, siltstone, and shale, with sandstone as the dominant lithology. The Cuyahoga Formation consists of gray to brown shale interbedded with minor sandstone and siltstone.
	Logan Formation Black Hand Formation (Mlb)	The Logan is a thin brown sandstone with minor siltstone and shale. The Black Hand is a massive sandstone with conglomerate and fractured zones. Moderate to good aquifers with yields ranging from 5 to 100 gallons per minute. Limited to the western third of Muskingum County.
	Logan and Cuyahoga Group (Mlcg)	Dark thin shales and siltstones with minor fine-grained sandstones that are stratigraphic equivalents of the Logan and Black Hand Formations. Moderate to poor aquifers, yields range from 5to 25 gallons per minute. Limited to southwestern Hopewell Township.

Weedman (1990) provides an excellent account of the complex depositional environments, which created the rocks of the Pennsylvanian System. These highly transitional environments included both terrestrial ("land-based") and marine-derived sediments. The terrestrial environment was dominated by large river systems featuring broad alluvial plains upland from coastal areas. Stream channels and point bar deposits were the source of sandstones and conglomerates. Shales and siltstones were derived from fine-grained floodplain deposits. Freshwater limestones were deposited in shallow, rapidly evaporating lakes and ponds found on the alluvial plain. The terrestrial environment was highly transitional with a marine environment over time. The position of the shoreline and the depth of water varied with the rate of sediment input into the basin, sea level, and the rate of subsidence. Subsidence refers to an uneven "settling" during the relatively rapid accumulation of sediments. In the Allegheny Group, sandstones and shales represent deltaic/shoreline environments. Marine limestones formed in slightly deeper waters, which lacked clastic input from rivers and deltas. Coal and clay were deposited in two different environments. Coal was deposited in either a "back-barrier" environment along the shoreline or in "deltaic-plain" environment in swamps formed in abandoned river channels (Horne et al., 1978). Similarly, clay was deposited in either quiet lagoonal areas directly behind the shoreline or in abandoned "oxbow" river channels (Ferm, 1974).

Ground Water Resources

Ground water in Muskingum County is obtained from both unconsolidated (glacial-alluvial) and consolidated (bedrock) aquifers. Glacial aquifers are primarily limited to the main trunk of the Muskingum River and its western tributaries.

Yields up to 500 gpm are obtainable from the coarse, well-sorted sand and gravel outwash deposits in the Muskingum River Valley (Walker, 1992 and ODNR, Div. of Water Open File, Glacial State Aquifer Map) east of Dresden and in the vicinity of Zanesville and Philo. Test drilling or geophysical methods are recommended to help locate the higher yielding zones. Proper well construction and development is also needed to insure the high sustainable yields capable from these larger diameter wells. Smaller diameter wells should be suitable for serving domestic/farm needs within this aquifer.

Yields of 100 to 500 gpm are obtained from somewhat thinner, less continuous outwash deposits (Walker, 1992 and ODNR, Div. of Water, Open File Glacial State Aquifer Map). Such deposits are found in the ancestral channel of the Muskingum River between Frazeysburg and Dresden, in the Licking River Valley northwest of Dillon Lake, and in the Muskingum River in the vicinity of Zanesville and Philo. Yields of 25 to 100 gpm (Walker, 1992) are obtained from wells drilled in the ancestral channel west of Frazeysburg and in the Muskingum River Valley between Dresden and Zanesville. Thin lenses of sand and gravel interbedded with finer-grained materials in the tributary buried valleys and alluvial valleys northwest of Zanesville yield 5 to 25 gpm (Walker, 1992).

Fine-grained deposits located in minor tributaries of the Muskingum River and Licking River in western Muskingum County typically are thin and constitute a very marginal aquifer

(Walker, 1992 and ODNR, Div. of Water, Open File, Glacial State Aquifer Map). These fine-grained deposits more likely help provide extra recharge to the underlying bedrock. Portions of these tributaries where thin, dirty sand and gravel lenses are present, interbedded with thicker sequences of fine-grained sediments, commonly yield less than 5 gpm (Walker, 1992 and ODNR, Div. of Water Open File, Glacial State Aquifer Map).

Yields from the consolidated, bedrock aquifers throughout the county are variable. Overall, yields tend to be better adjacent to stream valleys and poorer along ridge tops. Yields ranging from 10 to 25 gpm are common for other areas of interbedded sandstones and shales of the Mississippian Logan Formation and the Pennsylvanian Pottsville Group (Walker, 1992 and ODNR, Div. of Water, Open File, Bedrock State Aquifer Map). Yields from the Mississippian Maxville Limestone averages from 5 to 10 gpm (Walker, 1992 and Spahr, 1997a). Yields from wells developed in the dirty sandstones, shales, siltstones, coals, and thin limestones of the Allegheny Group usually range from 3 to 10 gpm (Walker, 1989 and ODNR, Div. of Water, Open File, Bedrock State Aquifer Map). Yields obtained from wells drilled in the dirty sandstones, shales, claystones, and limestones of the Conemaugh Group and Monongahela Group typically have meager yields averaging less than 3 gpm (Walker, 1992 and ODNR, Div. of Water, Open File, Bedrock State Aquifer Map).

The yield in any particular area is dependent upon the number and type of formations drilled. Wells drilled in bedrock often intersect several aquifers or water-producing zones. Sandstones and coals tend to be water-bearing units, whereas underclays, mudstones, siltstones and shales tend to be aquitards that impede the flow of water. Limestones are typically thin, hard, and fine-grained and are generally poor aquifers. Thicker, fractured limestones, however, are capable of producing suitable yields. Water tends to "perch" or collect on top of lower permeability units (e.g. shale) and move laterally along the base of an overlying unit with higher permeability (e.g. sandstone). Springs and seeps mark where these contacts meet the slope or land surface. Peffer (1991) demonstrated that shales could provide sufficient water to serve domestic needs and still behave as an aquitard.

The number of fractures and bedding planes intersected by the well also influences yields. The amount of fracturing tends to be greater in the valley bottoms than at the ridge tops. This increase may be related to stress relief, as shown by Wyrick and Borchers (1981) and Kipp et al. (1983). The net result is that there is usually a decrease in the depth to water (i.e. a shallower static water level) and slightly higher yields. Fracturing is also an influence on the direction of ground water flow (Schubert, 1980) and affects the amount of recharge.

Strip and Underground Mined Areas

The pollution potential of strip-mined and abandoned underground mined areas were not evaluated in Muskingum County. Although *DRASTIC: A Standardized System for Evaluating Ground Water Pollution Using Hydrogeologic Settings* (Aller et al., 1987) does identify mining as a possible source of ground water contamination, it does not discuss a methodology to evaluate the vulnerability of aquifers to contamination in these areas.

Many geologic and hydrogeologic changes occur in areas that have undergone or are undergoing mining and reclamation activities (Bonta et al., 1992 and Razem, 1983). The extent of these changes may not be known or may have a high degree of variability from one location to another.

Mining and reclamation activities have the ability to affect all DRASTIC parameters. Tables 10 and 11 list the DRASTIC parameters and the possible impacts that mining may have on rating the parameters in strip-mined and underground mined areas. These tables are not meant to be a comprehensive listing of the impacts of mining on ground water systems. They are provided to illustrate the uncertainty of evaluating the pollution potential of mined areas.

Although the pollution potential of strip and abandoned underground mined areas were not evaluated, they were delineated. Only the most prominent and conspicuous mined areas were delineated on the Pollution Potential Map of Muskingum County. Delineations of mined areas were made using information from the *Soil Survey of Muskingum County* (Steiger, 1996), abandoned underground mine maps (ODNR, Division of Geological Survey, open file maps), and the Muskingum County portion of U.S.G.S. 7-1/2 minute quadrangle maps. Site-specific information for mined area can be obtained from the ODNR, Division of Geological Survey and Division of Mineral Resources Management.

Table 10. Potential factors influencing DRASTIC ratings for strip mined areas

Parameter	Impact of Activity/Effects on DRASTIC Ratings
Depth to water	Removal of material overlying the aquifer will decrease the depth to water (i.e. increase DRASTIC rating); removal of uppermost aquifer will increase the depth to water (i.e. decrease DRASTIC rating)
Net Recharge	Mineral extraction and reclamation could increase the degree of fracturing, increase the permeability of the vadose zone and soils and therefore increase the amount of recharge (i.e. increase DRASTIC rating); compaction of fine grained spoils could decrease the amount of recharge to the aquifer (i.e. decrease DRASTIC rating)
Aquifer media	Mineral extraction could remove the uppermost aquifer
Soil media	Removal of soils will provide less of a barrier for contaminant transport (i.e. increase soil rating); reclaimed soils may have a lower permeability than the original cover (i.e. decrease soil rating)
Topography	Strip mining can change the contour of the land surface making delineation of this parameter virtually impossible
Impact of the vadose zone	Fracturing of vadose zone media could increase the permeability (i.e. increase rating); compaction of spoils during reclamation could decrease the permeability (i.e. decrease rating)
Hydraulic Conductivity	Fracturing of aquifer media could increase the conductivity (i.e. increase DRASTIC rating)

Table 11. Potential factors influencing DRASTIC ratings for underground mined areas

Parameter	Impact of Activity/Effects on DRASTIC Ratings
Depth to water	Collapse of underground mines has the potential to fracture overlying confining units, therefore causing a dewatering of overlying aquifers (i.e. decrease rating)
Net Recharge	Fracturing of overlying strata can increase amount of recharge to the aquifer (i.e. increase rating)
Aquifer media	Upper aquifers could be dewatered and underground mine could become the aquifer
Soil media	Fractures may extend to the land surface
Topography	This factor will not be affected unless severe subsidence occurs
Impact of the vadose zone	Fracturing and air shafts in the vadose zone could increase the permeability and provide a direct conduit for contamination (i.e. increase rating)
Hydraulic Conductivity	Upper aquifers not dewatered as a result of fracturing or subsidence would have higher conductivity values; underground mines serving as the aquifer media will have high conductivity values (i.e. higher rating)

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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 12,400 water well log records are on file for Muskingum County. Data from roughly 8,000 water well log records were analyzed and plotted on U.S.G.S. 7-1/2 minute topographic maps during the course of the project. Static water levels and information as to the depths at which water was encountered were taken from these records. The *Ground Water Resources of Muskingum County* (Walker, 1992) provided generalized depth to water information throughout the county. Depth to water trends mapped in adjoining Perry County (Spahr, 1997a; 1997b), Licking County (Angle, 1995), Morgan County (Angle et al., 2001) and Coshocton County (Spahr, 1995). Topographic and geomorphic trends were utilized in areas where other sources of data were lacking.

Depths to water of 5 to 15 feet (DRASTIC rating = 9) were typical of areas immediately adjacent to the Muskingum River, Licking River, and other major streams. Depths of 15 to 30 feet (7) were used for stream terraces adjacent to major streams and along smaller tributaries. Depths of 30 to 50 feet (5) were utilized for the headwaters of upland tributaries and for less steep slopes. Many moderately sloping areas, mantled by loess, have depths to water in the 30-50 feet (5) range. Depths to water of 50 to 75 feet were utilized for steeper slopes and lower ridge tops common throughout much of the county. Depths to water of 75 to 100 feet (2) and greater than 100 feet (1) were applied to very high, isolated ridge tops. These ridge tops are usually capped by thick sequences of fine-grained Pennsylvanian rocks.

Net Recharge

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

Values of 7 to 10 inches per year (8) were assigned to areas of the Muskingum River Buried Valley. These areas contain highly permeable soils, vadose, and aquifer materials, have shallow depths to water, gentle slopes, and surficial streams, and are limited to terraces and floodplains underlain by coarse-grained outwash deposits. Values of 4 to 7 inches per year (6) were used for areas with moderate recharge. These areas include most of the tributary and upland streams. These areas tend to have moderately shallow depths to water, surficial streams, and moderately permeable soils. Bedrock in these areas of stream valleys tends to be fractured. Values of 2 to 4 inches per year (3) were utilized for almost all upland slopes and ridge tops. The low permeability of the fine-grained soils and bedrock, the greater depths to water, and the high amount of run-off due to the steep slopes were the major factors for assigning the low recharge values. Values of recharge less than 2 inches per year (1) were utilized for limited ridge tops in Muskingum County. These areas have very great depths to water, soils are thin or absent and slopes are very steep which contribute to very high run-off. These rocks are commonly very low permeability units of the Conemaugh Group and Monongahela Group.

Aquifer Media

Information on aquifer media was obtained from the reports of Stout et al. (1943), Stout (1918), and Walker (1992). Mapping in adjoining Perry County Spahr, (1997a; 1997b), Coshocton County (Spahr, 1995), Morgan County (Angle et al., 1995) and Licking County (Angle, 1995) proved useful as a guideline for evaluating aquifers. Open File Bedrock Reconnaissance Maps based upon U.S.G.S. 7-1/2 minute topographic maps from the ODNR, Division of Geological Survey proved helpful. The ODNR, Division of Water, Glacial State Aquifer Map and Bedrock State Aquifer Map were an important source of aquifer data. Water well log records on file at the ODNR, Division of Water, were the primary source of aquifer information.

Aquifer ratings of (8) and (7) were assigned to relatively clean, well-sorted, coarse sand and gravel outwash deposits underlying the Muskingum River and the abandoned, buried channel underlying Frazeysburg. Aquifer ratings of (5) and (6) were selected for sand and gravel deposits found underlying tributary streams and valleys. These lower-rated sand and gravel aquifers tend to be thinner, are moderately-sorted and are finer-grained than the clean, higher-rated outwash deposits. Typically these lower-rated sand and gravel lenses were interbedded with thicker sequences of fine-grained alluvial or lacustrine deposits.

An aquifer rating of (6) was applied to a limited area of highly fractured, Pennsylvanian and Mississippian-age interbedded sandstones and shales in the northeastern corner of the county. An aquifer rating of (5) was utilized for the Mississippian-age Cuyahoga, Black Hand, and Logan formations in the western portion of the county. An aquifer rating of (4) was used for interbedded sandstones and shales of the Pennsylvanian Pottsville and Allegheny Group. An aquifer rating of (3) was used for the poor aquifers associated with the Pennsylvanian undivided (Monongahela and Conemaugh Groups)

Soils

Soils were mapped using the data obtained from the *Soil Survey of Muskingum County* (Steiger, 1996). Each soil type was evaluated and given a rating for soil media. Evaluations were based upon the texture, permeability, and shrink-swell potential for each soil material. The soils of Muskingum County showed a high degree of variability. This is a reflection of the parent material. Table 12 is a list of the soils, parent materials, setting, and corresponding DRASTIC values for Muskingum County.

Table 12. Muskingum County soils

Soil Name	Parent Material/Setting	DRASTIC Rating	Soil Media
Aaron	Fine-grained bedrock	7	Shrink/swell clay
Alford	Loess	4	Silty loam
Berks	Shale and sandstone slopes	10	Thin or absent
Bethesda	Strip mine	NR	
Brookside	Fine colluvium	7	Shrink/swell clay
Chagrin	Coarse alluvium	6	Sandy loam
Chavies	Coarse alluvium	6	Sandy loam
Chili	Fine outwash	6	Sandy loam
Chili Variant	Outwash	10	Gravel
Cidermill	Thin loess over outwash	6	Sandy loam
Cincinnati*	Till	3	Clay loam
Clarksburg	Coarse colluvium	3	Clay loam
Claysville-Guernsey	Fine colluvium	3	Clay loam
Coshocton	Siltstone and shale bedrock	3	Clay loam
Dumps & pits, mine	Strip mine	NR	
Fairpoint	Strip mine	NR	
Fitchville	Slack water deposits	4	Silty loam
Frankstown-Mertz	Chert	10	Thin or absent
Gilpin	Steep bedrock slope	10	Thin or absent
Glenford	Lacustrine, slack water	4	Silty loam
Guernsey-Upshur	Fine-grained bedrock	7	Shrink/swell clay
Homewood*	Till	3	Clay loam
Jimtown	Slack water terrace	6	Sandy loam
Keene*	Thick residuum or ridge tops	3	Clay loam
Killbuck	Lacustrine, slack water	4	Silty loam
Lakin	Dune/beach sand	9	Sand
Lakin-Alford	Fine dune over loess	9	Sand
Linside	Alluvium	4	Silty loam
Lobdell	Coarse alluvium	4	Silty loam
Lorain	Lacustrine	7	Shrink/swell clay
Lowell	Fine-grained bedrock	7	Shrink/swell clay
Lowell-Gilpin	Steep bedrock slope	10	Thin or absent
Luray	Lacustrine, depressional	4	Silty loam
Markland	Fine lacustrine	7	Shrink/swell clay
McGary	Lacustrine	7	Shrink/swell clay
Melvin	Alluvium	4	Silty loam
Mertz	Chert	4	Silty loam
Morristown	Strip mine	NR	
Newark	Recent alluvium	4	Silty loam
Nolin	Recent alluvium	4	Silty loam
Omulga*	Loess	3	Clay loam
Rawson	Loam over lacustrine	3	Clay loam
Rigley	Sandstone	6	Sandy loam
Rodman	Steep outwash terraces	10	Gravel
Sebring	Lacustrine	4	Silty loam
Stonelick	Coarse alluvium	6	Sandy loam
Tioga	Coarse alluvium	6	Sandy loam
Urban land-Glenford	Lacustrine, alluvial	4	Silty loam
Urban land-Nolin	Alluvium	4	Silty loam
Urban land-Watertown	Outwash terrace	10	Gravel
Urban land-Wellston	Loess over bedrock	4	Silty loam
Watertown	Outwash terraces	10	Gravel
Wellston	Loess, bedrock	10	Thin or absent
Westgate	Fine-grained bedrock	7	Shrink/swell clay
Westmoreland	Bedrock	4	Silty loam
Zanesville	Bedrock	4	Silty loam

* denotes soils containing fragipan

Soils were considered to be thin or absent (10) along many steep ridge tops and slopes where bedrock was exposed. Soils were rated as being a sand (9) or sandy loams (6) in outwash-rich area of the Muskingum River Buried Valley. Sandy loam soils (6) were also selected for residual sandstone ridges. Shrink-swell clays (7) were rated for upland areas having very clayey shale and mudstone bedrock residuum. Silt loam (4) soils were evaluated for silty shale and siltstone residuum on slopes and ridge tops and also for silty alluvial and lacustrine deposits on floodplains. Silt loam (4) was selected for soils developed on the loess-capped uplands and terraces. Clay loam (3) soils were evaluated for fine-grained bedrock residuum as well as finer-grained alluvial deposits in floodplains.

Certain soils in Muskingum County contain fragipans. A fragipan is a dense, impermeable zone found within certain loamy, till-derived soils. Fragipans may notably restrict the downward movement of water (Bureau et al., 1984 and Williams, 1990). The net effect of the fragipan is to reduce the overall permeability of a soil within a given textural range (Aller et al., 1987). Hence, a soil with a loam (5) texture would be evaluated as a silt loam (4), and a soil with a silt loam (4) texture would be evaluated as a clay loam (3) due to the presence of a fragipan.

Topography

Topography, or percent slope, was evaluated using U.S.G.S. 7-1/2 minute quadrangle maps and the *Soil Survey of Muskingum County* (Steiger, 1996). Slopes of 0 to 2 percent (10) and 2 to 6 percent (9) were selected for flat-lying floodplains, valley floors, and terraces. Slopes of 2 to 6 percent (9) and 6 to 12 percent (5) used for gentler, more rounded ridge tops. Slopes of 6 to 12 percent (5) were also used for less steep ridges, typically those flanking broader valleys and in areas with less resistant bedrock types. Slopes of 12 to 18 percent (3) and greater than 18 percent (1) were selected for steeper slopes in high relief, upland areas.

Impact of the Vadose Zone Media

Information on vadose zone media was obtained from the reports of Stout et al. (1943), Stout (1918), and Walker (1992). Mapping in adjoining Perry County Spahr, (1997a; 1997b), Coshocton County (Spahr, 1995), Morgan County (Angle et al., 1995) and Licking County (Angle, 1995) proved useful as a guideline for evaluating aquifers. Open File Bedrock Reconnaissance Maps based upon U.S.G.S. 7-1/2 minute topographic maps from the ODNR, Division of Geological Survey proved helpful. The ODNR, Division of Water, Glacial State Aquifer Map and Bedrock State Aquifer Map were an important source of vadose zone data. Water well log records on file at the ODNR, Division of Water, were the primary source of vadose zone information. Information on parent materials derived from the *Soil Survey of Muskingum County* (Steiger, 1996), also proved useful in evaluating vadose zone materials.

Vadose zone media was given a rating of (8) for sand and gravel, and ratings of (6), (7), and (8) for sand and gravel interbedded with silt and clay layers for the buried valley underlying the Muskingum River and portions of Moxahala Creek. These ratings depend upon the proportion of coarse, well-sorted outwash to the finer-grained alluvial and lacustrine deposits. Silt and clay with ratings of (4) and (5) were selected for vadose zone media for floodplains in many tributary valleys.

Vadose zone media was given a rating of (4) for the interbedded sandstone, shales, limestones, and coals of the Pennsylvanian System rocks that underlie the broader, upland stream valleys. It was determined that these rocks may contain more fracturing that is reflected by slightly higher yields in these areas. A vadose zone rating of (3) was utilized for the interbedded bedrock in ridge tops and higher slopes.

Hydraulic Conductivity

Published data for hydraulic conductivity for Muskingum County was found lacking. Information from Walker (1992), the ODNR, Division of Water, Glacial State Aquifer Map and Bedrock State Aquifer Map, and water well log records on file at the ODNR, Division of Water, were the primary sources of information. Hydraulic conductivity values utilized in adjoining Perry County (Spahr, 1997a; 1997b) and Muskingum County (Angle et al., 2001) proved to be a useful guideline. Textbook tables (Freeze and Cherry, Fetter, 1980, and Driscoll, 1986) were useful in obtaining estimated values for hydraulic conductivity in a variety of sediments.

Values for hydraulic conductivity correspond to aquifer ratings; i.e., the more highly rated aquifers have higher values for hydraulic conductivity. For sand and gravel aquifers with an aquifer rating of (8), hydraulic conductivity values of 1,000-2,000 gallons per day per square foot (gpd/ft^2) (8) were selected. These high values were limited to the clean outwash deposits of the Muskingum River Buried Valley. For sand and gravel deposits along the margins of the buried valley and in tributaries, hydraulic conductivities of 300-700 gpd/ft^2 (4) and 100-300 gpd/ft^2 (2) were used. In these deposits, thin sand and gravel lenses were interbedded with finer-grained materials.

All of the bedrock aquifers in Muskingum County were evaluated as having hydraulic conductivity values raging from 1-100 gpd/ft^2 (1) due to the overall low permeability of these interbedded sedimentary rocks.

APPENDIX B

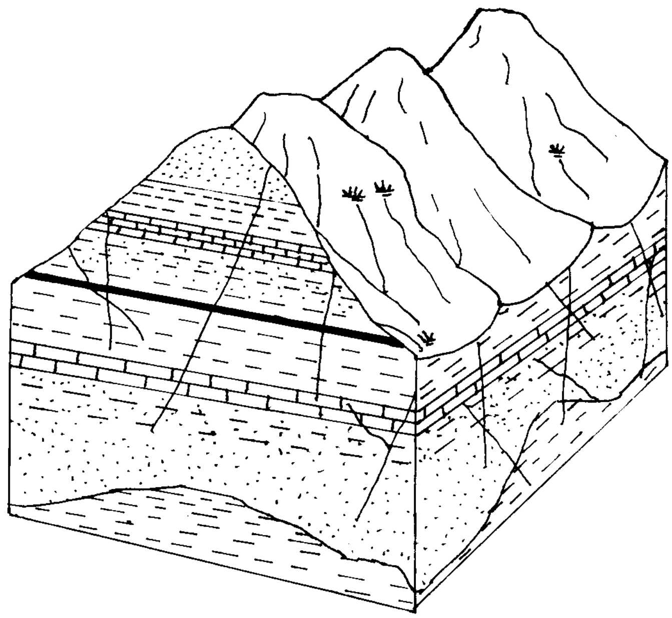
DESCRIPTION OF HYDROGEOLOGIC SETTINGS AND CHARTS

Ground water pollution potential mapping in Muskingum County resulted in the identification of 11 hydrogeologic settings within the Glaciated and Nonglaciated 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 13. Computed pollution potential indexes for Muskingum County range from 63 to 190.

Table 13. Hydrogeologic settings mapped in Muskingum County, Ohio

Hydrogeologic Settings	Range of GWPP Indexes	Number of Index Calculations
6Da - Alternating Sandstone, Limestone, Shale-Thin Regolith	63-11	141
6Db-Alternating Sandstone, Limestone, Shale-Thick Regolith	99	1
6Dc-Alternating Sandstone, Limestone, Shale-Thick Loess	76-117	15
6Fa-River Alluvium With Overbank Deposits	118-123	2
6Fb - River Alluvium Without Overbank Deposits	99-137	11
7Aa - Glacial Till Over Bedded Sedimentary Rock	68-83	4
7Bb-Outwash Over Bedded Sedimentary Rock	115-120	2
7D - Buried Valley	111-190	49
7Ec - Alluvium Over Bedded Sedimentary Rock	99	1
7Fa - Glacial Lakes and Slackwater Terraces	100-142	33
7G-Thin Glacial Till Over Bedded Sedimentary Rock	91-105	2

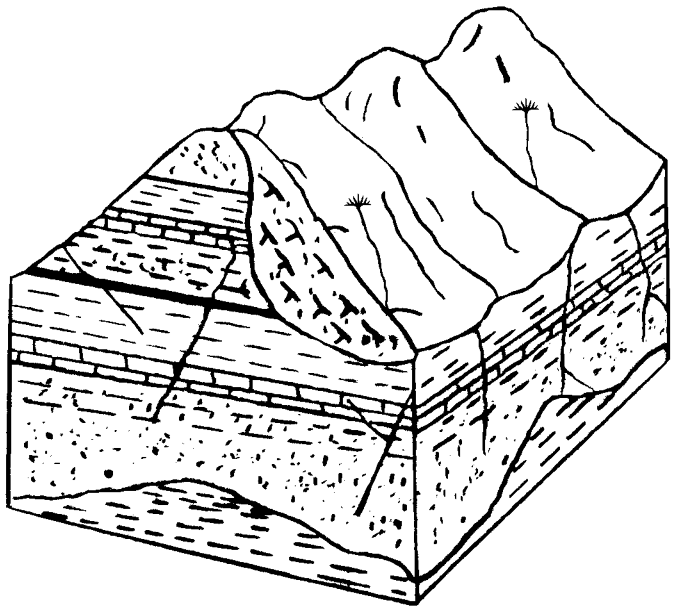
The following information provides a description of each hydrogeologic setting identified in the county, a block diagram illustrating the characteristics of the setting, and a listing of the charts for each unique combination of pollution potential indexes calculated for each setting. The charts provide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



6Da Alternating Sandstone, Limestone, Shale – Thin Regolith

This hydrogeologic setting is widespread, encompassing most upland areas in Muskingum County. The area is characterized by high relief with broad, steep slopes and narrow, somewhat flatter ridge tops. The vadose zone and aquifers consist of slightly dipping, fractured, alternating sequences of dirty sandstones, shales, thin limestones, clays, and coals of the Pennsylvanian and Mississippian Systems. Multiple aquifers are typically present. Depth to water is generally deep; shallower perched zones may overlie low permeability shales, limestones, and clays. Soils are generally thin to absent on steeper slopes. On gentler slopes, soils vary with the bedrock lithology. Small supplies of ground water are obtained from intersecting bedding planes or vertical fractures. Ground water yields average less than 25 gpm. Recharge is limited due to the steep slopes, deep aquifers, and layers of impermeable bedrock.

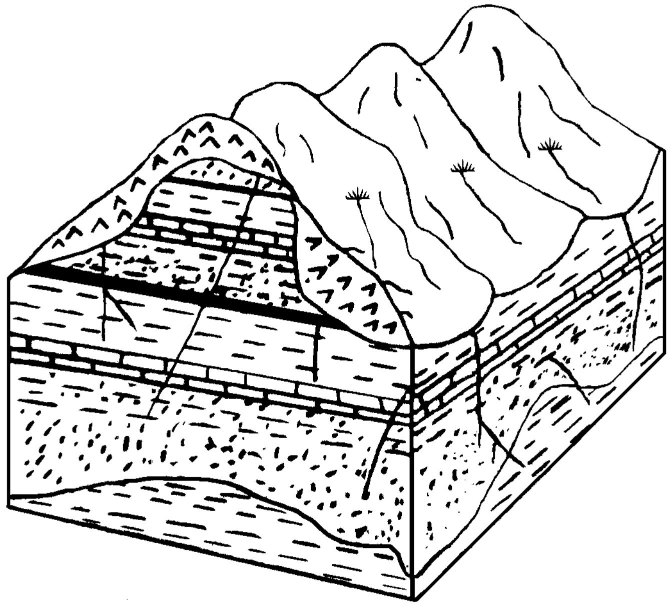
GWPP index values for the hydrogeologic setting of Alternating Sandstone, Limestone, Shale – Thin Regolith range from 63 to 111, with the total number of GWPP index calculations equaling 141.



6Db Alternating Sandstone, Limestone, Shale – Thick Regolith

This hydrogeologic setting is limited to slopes found along the western margin of Muskingum County, bordering Licking County. The area is similar to the 6Da Alternating Sandstone, Limestone, Shale-Thin Regolith setting, except that the regolith is much thicker, creating a flat-lying toe at the base of the slopes. The vadose zone and aquifers consist of slightly dipping, fractured, alternating sequences of dirty sandstones, shales, thin limestones, clays, and coals of the Pennsylvanian System and sandstones, shales, siltstones and limestones of the Mississippian System. Multiple aquifers are typically present. Depth to water is moderately deep and transitional between stream valleys and ridge tops. Soils are silt loams that formed in thick regolith and colluvium derived from shales and siltstones. Small supplies of ground water are obtained from intersecting bedding planes or vertical fractures. Ground water yields average less than 25 gpm. Recharge is moderate due to the moderate depth to water, flat-lying slope, and layers of impermeable bedrock.

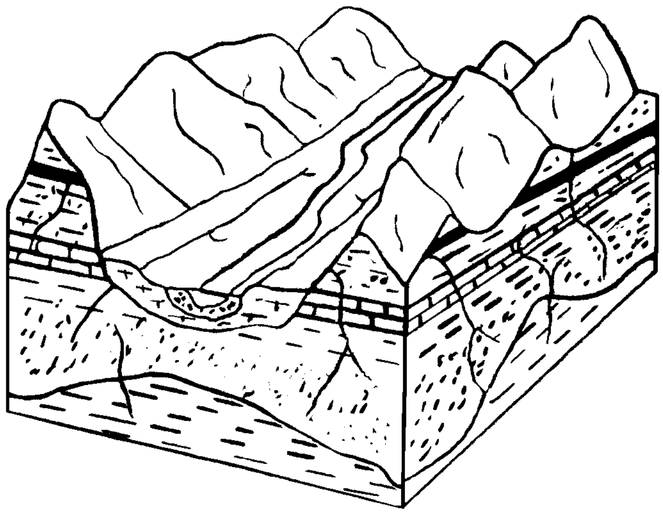
The GWPP index value for the hydrogeologic setting Alternating Sandstone, Limestone, Shale-Thick Regolith is 99, with the total number of GWPP index calculations equaling 1.



6Dc Alternating Sandstone, Limestone, Shale – Thick Loess

This hydrogeologic setting is found along broad slopes and ridge tops adjacent to stream valleys in central Muskingum County. The setting is characterized by thick accumulations of loess that blanket slopes and ridge tops downwind from major stream valleys. These loess caps tend to modify the topography, making slopes less steep and more rolling. The loess is windblown silt that was eroded from floodplains of stream valleys and outwash terraces. Aquifers consist of slightly dipping, fractured, alternating sequences of dirty sandstones, shales, thin limestones, clays, and coals of the Pennsylvanian System and sandstones, siltstones, shales, and limestones of the Mississippian System. Multiple aquifers are typically present. The vadose zone consists of silty loess. Soils are silt loams derived from the loess caps. The loess may merge with higher-level slack water lacustrine deposits. Depth to water is generally moderate. Small supplies of ground water are obtained from intersecting bedding planes or vertical fractures. Ground water yields average less than 25 gpm. The vadose zone consists of silty to clayey loess. Soils are silt loams derived from the loess caps. Recharge is moderate due to moderate slopes and depth to water and lower permeability vadose and aquifers.

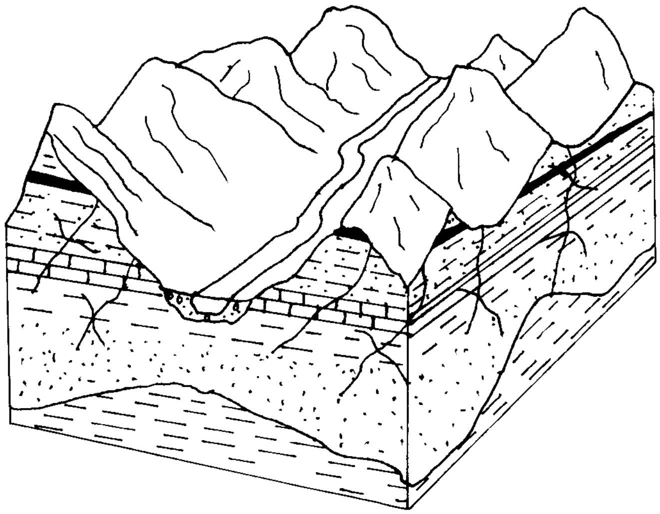
GWPP index values for the hydrogeologic setting of Alternating Sandstone, Limestone, Shale – Thick Loess range from 76 to 117, with the total number of GWPP index calculations equaling 15.



6Fa River Alluvium with Overbank Deposits

This hydrogeologic setting is limited to small tributary valleys in the uplands of western Muskingum County. This setting is somewhat similar to the 7Fa Glacial Lakes and Slackwater Terraces setting; however, the valleys and floodplains are narrower and the alluvial deposits are much thinner. Areas in this setting are similar to the adjacent uplands, which belong to the 6Da Alternating Sandstone, Limestone, Shale - Thin Regolith setting. Narrow, relatively flat-bottomed stream valleys flanked by steep bedrock ridges characterize the setting. Depth to water is usually shallow, averaging less than 30 feet. Soils are generally silt loams. The alluvium is composed primarily of fine-grained floodplain ("overbank") sediments. The alluvial deposits are typically saturated; however, the alluvium is too thin to be utilized as an aquifer. The aquifer is the underlying dirty sandstones, shales, thin limestones, claystones, clays and coals of the Pennsylvanian System and sandstones, siltstones, shales, and limestones of the Mississippian System. In most areas, the alluvium is in direct connection with the underlying bedrock aquifers. Ground water yields average less than 25 gpm. Recharge is moderate due to the relatively shallow depth to water, flatter topography, and the relatively low permeability of the bedrock. Recharge is higher than the surrounding uplands.

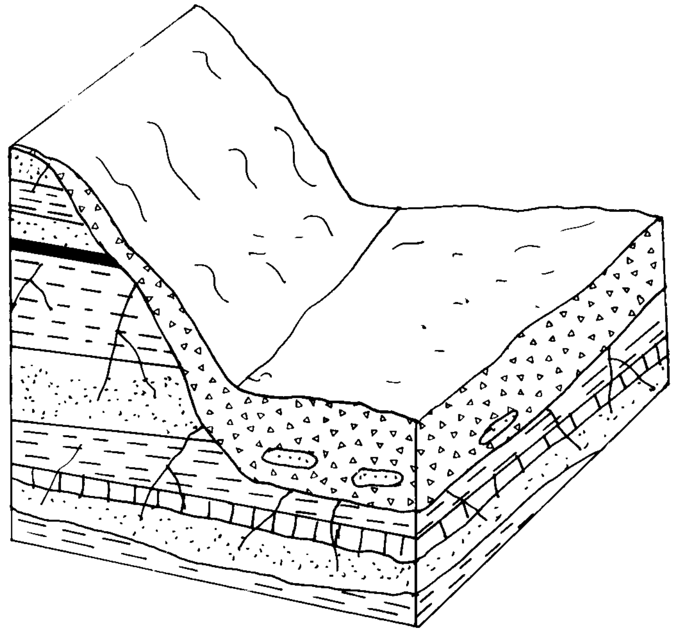
GWPP index values for the hydrogeologic setting of River Alluvium with Overbank Deposits range from 118 to 123, with the total number of GWPP index calculations equaling 2.



6Fb River Alluvium without Overbank Deposits

This hydrogeologic setting is limited to the headwaters of small tributary valleys in the uplands throughout Muskingum County. This setting is somewhat similar to the 6Fa River Alluvium with Overbank Deposits setting; however, the valleys and floodplains are more narrow, terraces are absent, and the alluvial deposits are much thinner and coarser-grained. Areas in this setting are similar to the adjacent uplands, which belong to the 6Da Alternating Sandstone, Limestone, Shale - Thin Regolith setting. The headwaters of narrow, relatively flat-bottomed stream valleys flanked by steep bedrock ridges characterize the setting. Depth to water is usually moderate, averaging less than 50 feet. Soils are generally silt loams. The alluvium is composed primarily of fine-grained to coarse-grained sediments. The alluvial deposits are typically saturated; however, the alluvium is too thin to be utilized as an aquifer. The aquifer is the underlying dirty sandstones, shales, thin limestones, claystones, clays and coals of the Pennsylvanian System and sandstones, siltstones, shales, and limestones of the Mississippian System. In most areas, the alluvium is in direct connection with the underlying bedrock aquifers. Ground water yields average less than 25 gpm. Recharge is moderate due to the relatively shallow depth to water, flatter topography, and the relatively low permeability of the bedrock. Recharge is higher than the surrounding uplands.

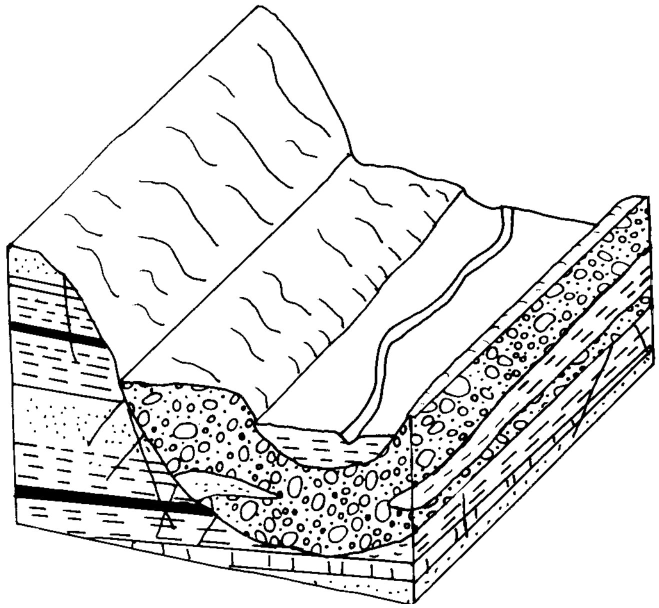
GWPP index values for the hydrogeologic setting of River Alluvium without Overbank Deposits range from 99 to 137, with the total number of GWPP index calculations equaling 11.



7Aa Glacial Till over Bedded Sedimentary Rock

This hydrogeologic setting is limited to slopes found along the western margin of Muskingum County, bordering Licking County. The area is similar to the 6Da Alternating Sandstone, Limestone, Shale-Thin Regolith except that the landscape has a moderate covering of glacial till. The till is commonly relatively thin, weathered and may be fractured. Slopes are somewhat less steep and more subdued by the glacial till cover than in adjacent non-glaciated areas. The vadose zone and aquifers consist of slightly dipping, fractured, alternating sequences of dirty sandstones, shales, thin limestones, clays, and coals of the Pennsylvanian System and sandstones, siltstones, shales, and limestones of the Mississippian System. Multiple aquifers are typically present. Depth to water is generally deep; shallower perched zones may overlie low permeability shales, limestones, and clays. Soils are generally clay loams derived from the till. Small supplies of ground water are obtained from intersecting bedding planes or vertical fractures. Ground water yields average less than 25 gpm. Recharge is limited due to the deep aquifers, low permeability soils, vadose zone material, and aquifers.

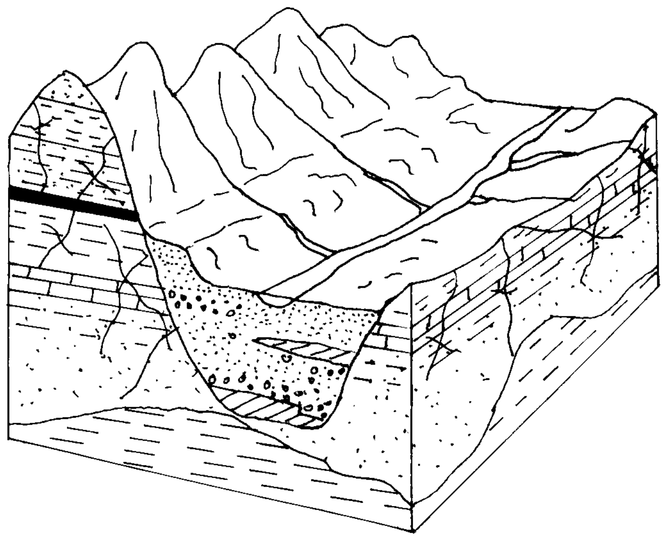
GWPP index values for the hydrogeologic setting of Glacial Till over Bedded Sedimentary Rock range from 68 to 83, with the total number of GWPP index calculations equaling 4.



7Bb Outwash over Bedded Sedimentary Rocks

This hydrogeologic setting consists of relatively small, high-level outwash terraces that set on top of bedrock benches. These terraces are limited to the margins or tributaries to the buried valleys. The total thickness of drift is not adequate to be considered buried valleys. Relief is low and the flat to rolling terraces occurs at higher elevations than the modern floodplain. Vadose zone media consists of bedded sandy to gravelly outwash interbedded with finer alluvial deposits. Soils vary from silt loam to sandy loam, depending upon whether fine alluvial material is capping the coarser outwash. The outwash terraces are not thick enough to comprise the aquifer; underlying fractured, interbedded sandstones, shales, limestones, and coals of the Mississippian and Pennsylvanian Systems serve as the aquifer. Yields average 10 to 25 gpm. The overlying terraces are typically in direct contact with the underlying bedrock aquifer. Depth to water is moderate due to local relief. Recharge is moderately high due to the relatively permeable soils and vadose, moderate to shallow depth to water, and relatively flat to rolling topography.

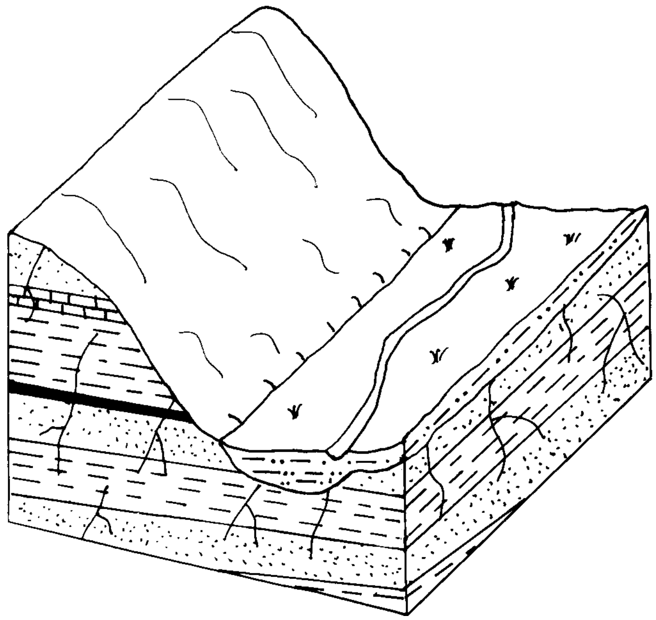
GWPP index values for the hydrogeologic setting of Outwash over Bedded Sedimentary Rocks range from 115 to 120, with the total number of GWPP index calculations equaling 2.



<u>7D Buried Valley</u>

This hydrogeologic setting is widespread throughout Muskingum County. All of the major trunk streams and some of the modern tributaries overlie buried valley deposits. There are also former drainage ways overlying buried valleys that lack modern streams, notably the broad valley extending westward from Frazeysburg. Broad, flat-lying floodplains and gently sloping terraces characterize the setting. Depths to water are variable; they are typically less than 30 feet in valleys containing modern streams and are commonly over 45 feet in valleys lacking modern streams. Aquifers are composed of variable thicknesses of sand and gravel interbedded with finer-grained alluvium, till, and lacustrine deposits. The modern streams may be in direct hydraulic connection with the underlying aquifer. Yields up to 500 gpm have been reported for some of the coarser, thicker, more continuous sand and gravel outwash in portions of the Muskingum River Valley and Licking River Valley. Yields up to 100 gpm are developed in remaining portions of the Muskingum River Valley and Licking River Valley. Some valleys, including Wills Creek and the tributary valleys east of the Licking River, contain thin lenses of sand and gravel interbedded with much thicker sequences of finer-grained alluvial and lacustrine deposits. Soils on terraces are typically sandy loams derived from outwash; soils on floodplains are silt loams derived from modern alluvium. Recharge is typically relatively high due to the flat-lying topography, shallow depth to water, and the high permeability of the soils, vadose zone materials, and aquifer for buried valleys with modern overlying streams. Recharge tends to be less in valleys lacking modern streams, having greater depths to water, and less permeable soils and vadose media.

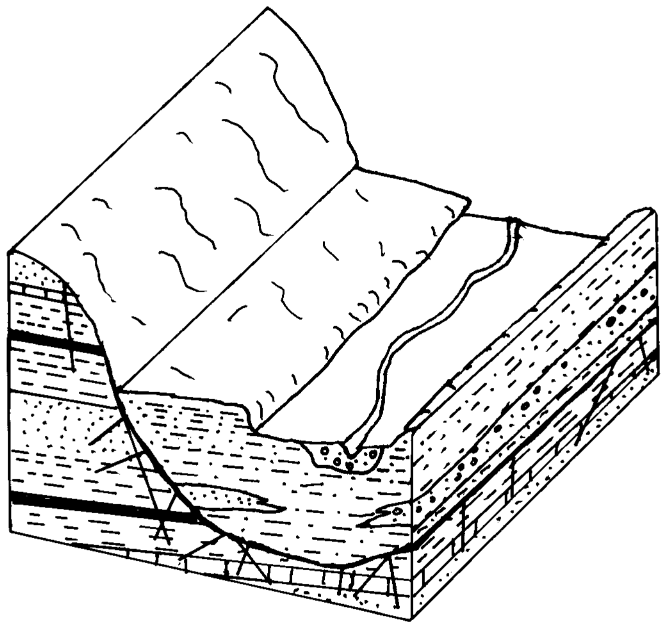
GWPP index values for the hydrogeologic setting of Buried Valley range from 111 to 190, with the total number of GWPP index calculations equaling 49.



7Ec Alluvium Over Bedded Sedimentary Rock

The setting consists of the headwaters of small tributary streams in upland areas with thin glacial cover in southwestern Muskingum County. These tributaries flow southward into Perry County. This setting is similar to the 6Fa River Alluvium with Overbank Deposits except that the stream alluvium overlies some additional glacial drift. The setting is characterized by narrow, flat-bottomed stream valleys, which are flanked by rolling to steep bedrock-controlled uplands. The aquifer consists of fractured, interbedded sandstones, shales, limestones and coals of the Pennsylvanian System and interbedded shales, siltstones, and fine-grained sandstones of the Mississippian System. Yields developed from the fractures and bedding planes of the bedrock range from 10 to 25 gpm. Soils are silt loams. Vadose zone media is typically either silty alluvium or the underlying till or other glacial drift. The depth to water is commonly shallow, averaging from 10 to 35 feet. Recharge is moderately high due to the shallow depth to water, flat-lying topography, proximity of modern streams, and the moderately low permeability of the soils, alluvium, and bedrock.

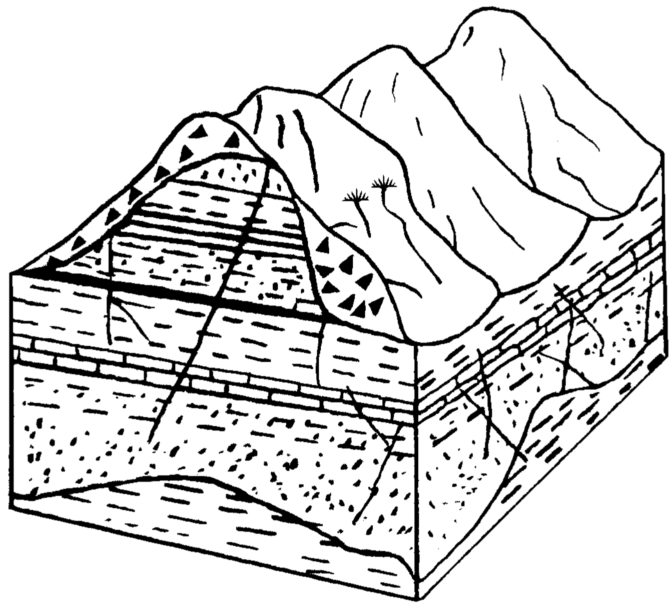
The GWPP index value for the hydrogeologic setting Alluvium over Bedded Sedimentary Rock is 99, with the total number of GWPP index calculations equaling 1.



7Fa Glacial Lakes and Slackwater Terraces

Flat-lying areas that were formed in low velocity water of glacial and slack water lakes that filled pre-existing drainage systems characterize this setting. These areas are typically dissected by modern streams and contain remnant low-lying terraces. These streams include most of the major tributaries of the Muskingum River and Licking River. The valleys are typically broader and contain thicker drift than the somewhat similar 6Fa River Alluvium with Overbank Deposits. The setting is bordered by steep bedrock uplands. The drift is not as thick or as coarse as in adjacent 7D Buried Valley settings. The aquifer consists of thin sand and gravel lenses interbedded with finer lacustrine and alluvial deposits. If sand and gravel is not encountered, wells are completed in the underlying interbedded sedimentary rock. Depth to water is commonly shallow due to the presence of streams found within this setting. Vadose zone material consists of silty alluvium. Soils are silt loams. Recharge in this setting is moderate due to the relatively shallow depth to water, flat-lying topography, and the moderate to low permeability soils, vadose, and underlying bedrock.

GWPP index values for the hydrogeologic setting of Glacial Lakes and Slackwater Terraces range from 100 to 142, with the total number of GWPP index calculations equaling 33.



7G Thin Glacial Till Over Bedded Sedimentary Rock

This hydrogeologic setting is limited to slopes found along the western margin of Muskingum County, bordering Licking County. This hydrogeologic setting is characterized by rolling to steep bedrock-controlled topography and deposits of thin, patchy glacial till overlying alternating layers of fractured sedimentary rock. This setting is limited to southwestern Hopewell Township along the boundary with Perry County. The setting is similar to the 7Aa Glacial Till over Bedded Sedimentary Rock setting except that the till is thinner and less continuous. The till is less than 25 feet thick and consists of varying amounts of unsorted clay, silt, and sand with minor pebbles and cobbles. The till is typically highly weathered and may be fractured. Ground water is obtained from the underlying fractured Mississippian or Pennsylvanian bedrock. Depth to water is moderate, partially because the setting consists of moderately steep slopes. Soils are silt loams. Recharge is low due to depth to water, relatively steep slopes, and relatively impermeable nature of the soils and vadose.

GWPP index values for the hydrogeologic setting of Thin Glacial Till Over Bedded Sedimentary Rock range from 91 to 105, with the total number of GWPP index calculations equaling 2.

Table 14. Hydrogeologic Settings, DRASTIC Factors, and Ratings

Setting	Depth To Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% Slope)	Vadose Zone Media	Hydraulic Conductivity	Rating
6Da001	50-75	2-4	interbedded ss/sh/ls/coal	Silty Loam	18+	interbedded ss/sh/ls/coal	100-300	77
6Da002	50-75	2-4	interbedded ss/sh/ls/coal	Sandy Loam	18+	interbedded ss/sh/ls/coal	100-300	81
6Da003	50-75	2-4	interbedded ss/sh/ls/coal	Clay Loam	18+	interbedded ss/sh/ls/coal	100-300	75
6Da004	50-75	0-2	interbedded ss/sh/ls/coal	Sandy Loam	18+	interbedded ss/sh/ls/coal	100-300	73
6Da005	50-75	2-4	interbedded ss/sh/ls/coal	Sandy Loam	12-18	interbedded ss/sh/ls/coal	100-300	83
6Da006	50-75	2-4	interbedded ss/sh/ls/coal	Loam	12-18	interbedded ss/sh/ls/coal	100-300	81
6Da007	50-75	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	18+	interbedded ss/sh/ls/coal	100-300	89
6Da008	50-75	2-4	interbedded ss/sh/ls/coal	Clay Loam	12-18	interbedded ss/sh/ls/coal	100-300	77
6Da009	75-100	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	6-12	interbedded ss/sh/ls/coal	100-300	82
6Da010	50-75	2-4	interbedded ss/sh/ls/coal	Clay Loam	6-12	interbedded ss/sh/ls/coal	100-300	79
6Da011	50-75	2-4	interbedded ss/sh/ls/coal	Sandy Loam	18+	interbedded ss/sh/ls/coal	100-300	81
6Da012	75-100	2-4	interbedded ss/sh/ls/coal	Clay Loam	6-12	interbedded ss/sh/ls/coal	100-300	74
6Da013	50-75	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	18+	interbedded ss/sh/ls/coal	100-300	83
6Da014	75-100	2-4	interbedded ss/sh/ls/coal	Silty Loam	2-6	interbedded ss/sh/ls/coal	100-300	80
6Da015	75-100	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	18+	interbedded ss/sh/ls/coal	1-100	72
6Da016	75-100	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	6-12	interbedded ss/sh/ls/coal	1-100	76
6Da017	50-75	2-4	interbedded ss/sh/ls/coal	Clay Loam	18+	interbedded ss/sh/ls/coal	1-100	69
6Da018	50-75	2-4	interbedded ss/sh/ls/coal	Loam	18+	interbedded ss/sh/ls/coal	100-300	79
6Da019	50-75	2-4	interbedded ss/sh/ls/coal	Loam	18+	interbedded ss/sh/ls/coal	1-100	73
6Da020	50-75	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	18+	interbedded ss/sh/ls/coal	1-100	83
6Da021	30-50	2-4	interbedded ss/sh/ls/coal	Clay Loam	18+	interbedded ss/sh/ls/coal	1-100	76
6Da022	50-75	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	18+	interbedded ss/sh/ls/coal	1-100	75
6Da023	75-100	2-4	interbedded ss/sh/ls/coal	Clay Loam	18+	interbedded ss/sh/ls/coal	1-100	61
6Da024	50-75	2-4	interbedded ss/sh/ls/coal	Silty Loam	18+	interbedded ss/sh/ls/coal	1-100	71
6Da025	50-75	2-4	interbedded ss/sh/ls/coal	Clay Loam	12-18	interbedded ss/sh/ls/coal	1-100	71
6Da026	75-100	2-4	interbedded ss/sh/ls/coal	Silty Loam	18+	interbedded ss/sh/ls/coal	1-100	63

Setting	Depth To Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% Slope)	Vadose Zone Media	Hydraulic Conductivity	Rating
6Da027	75-100	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	18+	interbedded ss/sh/ls/coal	1-100	78
6Da028	75-100	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	12-18	interbedded ss/sh/ls/coal	1-100	66
6Da029	75-100	2-4	interbedded ss/sh/ls/coal	Sandy Loam	18+	interbedded ss/sh/ls/coal	1-100	67
6Da030	50-75	2-4	interbedded ss/sh/ls/coal	Sandy Loam	18+	interbedded ss/sh/ls/coal	1-100	75
6Da031	50-75	2-4	interbedded ss/sh/ls/coal	Silty Loam	18+	interbedded ss/sh/ls/coal	1-100	63
6Da032	75-100	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	6-12	interbedded ss/sh/ls/coal	1-100	68
6Da033	75-100	2-4	interbedded ss/sh/ls/coal	Silty Loam	18+	interbedded ss/sh/ls/coal	1-100	58
6Da034	75-100	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	18+	interbedded ss/sh/ls/coal	1-100	70
6Da035	75-100	2-4	interbedded ss/sh/ls/coal	Clay Loam	18+	interbedded ss/sh/ls/coal	1-100	56
6Da036	50-75	2-4	interbedded ss/sh/ls/coal	Sandy Loam	12-18	interbedded ss/sh/ls/coal	100-300	83
6Da037	30-50	2-4	interbedded ss/sh/ls/coal	Sandy Loam	12-18	interbedded ss/sh/ls/coal	100-300	93
6Da038	30-50	2-4	interbedded ss/sh/ls/coal	Silty Loam	6-12	interbedded ss/sh/ls/coal	100-300	91
6Da039	75-100	2-4	interbedded ss/sh/ls/coal	Silty Loam	6-12	interbedded ss/sh/ls/coal	100-300	76
6Da040	75-100	2-4	interbedded ss/sh/ls/coal	Clay Loam	18+	interbedded ss/sh/ls/coal	100-300	70
6Da041	30-50	2-4	interbedded ss/sh/ls/coal	Sandy Loam	18+	interbedded ss/sh/ls/coal	100-300	91
6Da042	30-50	2-4	interbedded ss/sh/ls/coal	Clay Loam	18+	interbedded ss/sh/ls/coal	100-300	85
6Da043	75-100	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	2-6	interbedded ss/sh/ls/coal	100-300	92
6Da044	50-75	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	6-12	interbedded ss/sh/ls/coal	100-300	87
6Da045	50-75	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	12-18	interbedded ss/sh/ls/coal	1-100	79
6Da046	30-50	2-4	interbedded ss/sh/ls/coal	Silty Loam	18+	interbedded ss/sh/ls/coal	100-300	87
6Da047	75-100	2-4	interbedded ss/sh/ls/coal	Clay Loam	2-6	interbedded ss/sh/ls/coal	100-300	78
6Da048	75-100	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	2-6	interbedded ss/sh/ls/coal	100-300	86
6Da049	75-100	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	2-6	interbedded ss/sh/ls/coal	1-100	80
6Da050	30-50	2-4	interbedded ss/sh/ls/coal	Clay Loam	6-12	interbedded ss/sh/ls/coal	100-300	89
6Da051	50-75	2-4	interbedded ss/sh/ls/coal	Clay Loam	2-6	interbedded ss/sh/ls/coal	100-300	83
6Da052	30-50	2-4	interbedded ss/sh/ls/coal	Clay Loam	12-18	interbedded ss/sh/ls/coal	100-300	87
6Da053	75-100	2-4	interbedded ss/sh/ls/coal	Clay Loam	12-18	interbedded ss/sh/ls/coal	100-300	72

Setting	Depth To Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% Slope)	Vadose Zone Media	Hydraulic Conductivity	Rating
6Da054	75-100	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	6-12	interbedded ss/sh/ls/coal	100-300	88
6Da055	100+	2-4	interbedded ss/sh/ls/coal	Clay Loam	2-6	interbedded ss/sh/ls/coal	100-300	73
6Da056	100+	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	2-6	interbedded ss/sh/ls/coal	100-300	87
6Da057	30-50	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	6-12	interbedded ss/sh/ls/coal	100-300	103
6Da058	75-100	2-4	interbedded ss/sh/ls/coal	Clay Loam	6-12	interbedded ss/sh/ls/coal	1-100	68
6Da059	75-100	2-4	interbedded ss/sh/ls/coal	Silty Loam	12-18	interbedded ss/sh/ls/coal	1-100	68
6Da060	75-100	2-4	interbedded ss/sh/ls/coal	Clay Loam	2-6	interbedded ss/sh/ls/coal	1-100	72
6Da061	50-75	2-4	interbedded ss/sh/ls/coal	Clay Loam	6-12	interbedded ss/sh/ls/coal	1-100	73
6Da062	50-75	2-4	interbedded ss/sh/ls/coal	Silty Loam	12-18	interbedded ss/sh/ls/coal	1-100	73
6Da063	75-100	2-4	interbedded ss/sh/ls/coal	Clay Loam	18+	interbedded ss/sh/ls/coal	1-100	64
6Da064	75-100	2-4	interbedded ss/sh/ls/coal	Silty Loam	2-6	interbedded ss/sh/ls/coal	1-100	74
6Da065	50-75	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	18+	interbedded ss/sh/ls/coal	1-100	77
6Da066	75-100	2-4	interbedded ss/sh/ls/coal	Silty Loam	6-12	interbedded ss/sh/ls/coal	1-100	70
6Da067	30-50	2-4	interbedded ss/sh/ls/coal	Silty Loam	6-12	interbedded ss/sh/ls/coal	1-100	85
6Da068	15-30	2-4	interbedded ss/sh/ls/coal	Silty Loam	6-12	interbedded ss/sh/ls/coal	1-100	95
6Da069	30-50	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	18+	interbedded ss/sh/ls/coal	1-100	93
6Da070	50-75	2-4	interbedded ss/sh/ls/coal	Silty Loam	12-18	interbedded ss/sh/ls/coal	100-300	79
6Da071	75-100	2-4	interbedded ss/sh/ls/coal	Silty Loam	12-18	interbedded ss/sh/ls/coal	100-300	74
6Da072	30-50	2-4	interbedded ss/sh/ls/coal	Clay Loam	18+	interbedded ss/sh/ls/coal	1-100	79
6Da073	30-50	2-4	interbedded ss/sh/ls/coal	Clay Loam	12-18	interbedded ss/sh/ls/coal	1-100	81
6Da074	30-50	2-4	interbedded ss/sh/ls/coal	Clay Loam	6-12	interbedded ss/sh/ls/coal	1-100	83
6Da075	30-50	2-4	interbedded ss/sh/ls/coal	Clay Loam	12-18	interbedded ss/sh/ls/coal	1-100	81
6Da076	30-50	2-4	interbedded ss/sh/ls/coal	Clay Loam	2-6	interbedded ss/sh/ls/coal	1-100	87
6Da077	30-50	2-4	interbedded ss/sh/ls/coal	Silty Loam	12-18	interbedded ss/sh/ls/coal	1-100	83
6Da078	30-50	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	6-12	interbedded ss/sh/ls/coal	1-100	97
6Da079	15-30	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	2-6	interbedded ss/sh/ls/coal	1-100	111
6Da080	30-50	2-4	interbedded ss/sh/ls/coal	Silty Loam	18+	interbedded ss/sh/ls/coal	1-100	81

Setting	Depth To Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% Slope)	Vadose Zone Media	Hydraulic Conductivity	Rating
6Da081	50-75	2-4	interbedded ss/sh/ls/coal	Sand	6-12	interbedded ss/sh/ls/coal	1-100	85
6Da082	75-100	2-4	interbedded ss/sh/ls/coal	Clay Loam	6-12	interbedded ss/sh/ls/coal	1-100	68
6Da083	50-75	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	6-12	interbedded ss/sh/ls/coal	1-100	81
6Da084	75-100	0-2	interbedded ss/sh/ls/coal	Thin/Absent Gravel	6-12	interbedded ss/sh/ls/coal	1-100	74
6Da085	50-75	2-4	interbedded ss/sh/ls/coal	Clay Loam	2-6	interbedded ss/sh/ls/coal	1-100	77
6Da086	30-50	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	2-6	interbedded ss/sh/ls/coal	1-100	101
6Da087	75-100	0-2	interbedded ss/sh/ls/coal	Thin/Absent Gravel	2-6	interbedded ss/sh/ls/coal	1-100	78
6Da088	50-75	0-2	interbedded ss/sh/ls/coal	Thin/Absent Gravel	18+	interbedded ss/sh/ls/coal	1-100	75
6Da089	50-75	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	6-12	interbedded ss/sh/ls/coal	1-100	73
6Da090	50-75	2-4	interbedded ss/sh/ls/coal	Silty Loam	12-18	interbedded ss/sh/ls/coal	1-100	65
6Da091	50-75	2-4	interbedded ss/sh/ls/coal	Clay Loam	18+	interbedded ss/sh/ls/coal	1-100	61
6Da092	50-75	2-4	interbedded ss/sh/ls/coal	Silty Loam	6-12	interbedded ss/sh/ls/coal	1-100	67
6Da093	75-100	2-4	interbedded ss/sh/ls/coal	Silty Loam	6-12	interbedded ss/sh/ls/coal	1-100	62
6Da094	50-75	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	18+	interbedded ss/sh/ls/coal	1-100	75
6Da095	30-50	2-4	interbedded ss/sh/ls/coal	Silty Loam	18+	interbedded ss/sh/ls/coal	1-100	78
6Da096	50-75	2-4	interbedded ss/sh/ls/coal	Clay Loam	12-18	interbedded ss/sh/ls/coal	1-100	63
6Da097	50-75	2-4	interbedded ss/sh/ls/coal	Sandy Loam	18+	interbedded ss/sh/ls/coal	1-100	67
6Da098	30-50	2-4	interbedded ss/sh/ls/coal	Clay Loam	12-18	interbedded ss/sh/ls/coal	1-100	78
6Da099	75-100	2-4	interbedded ss/sh/ls/coal	Clay Loam	6-12	interbedded ss/sh/ls/coal	1-100	60
6Da100	50-75	2-4	interbedded ss/sh/ls/coal	Clay Loam	2-6	interbedded ss/sh/ls/coal	1-100	69
6Da101	75-100	2-4	interbedded ss/sh/ls/coal	Clay Loam	2-6	interbedded ss/sh/ls/coal	1-100	64
6Da102	75-100	2-4	interbedded ss/sh/ls/coal	Sandy Loam	6-12	interbedded ss/sh/ls/coal	1-100	66
6Da103	30-50	2-4	interbedded ss/sh/ls/coal	Silty Loam	2-6	interbedded ss/sh/ls/coal	1-100	86
6Da104	50-75	2-4	interbedded ss/sh/ls/coal	Clay Loam	6-12	interbedded ss/sh/ls/coal	1-100	65
6Da105	50-75	0-2	interbedded ss/sh/ls/coal	Thin/Absent Gravel	18+	interbedded ss/sh/ls/coal	1-100	67
6Da107	30-50	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	6-12	interbedded ss/sh/ls/coal	1-100	83
6Da108	50-75	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	6-12	interbedded ss/sh/ls/coal	1-100	79

Setting	Depth To Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% Slope)	Vadose Zone Media	Hydraulic Conductivity	Rating
6Da109	30-50	2-4	interbedded ss/sh/ls/coal	Silty Loam	18+	interbedded ss/sh/ls/coal	1-100	73
6Da110	50-75	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	18+	interbedded ss/sh/ls/coal	1-100	69
6Da111	30-50	2-4	interbedded ss/sh/ls/coal	Clay Loam	6-12	interbedded ss/sh/ls/coal	1-100	75
6Da112	30-50	2-4	interbedded ss/sh/ls/coal	Clay Loam	18+	interbedded ss/sh/ls/coal	1-100	71
6Da113	30-50	2-4	interbedded ss/sh/ls/coal	Clay Loam	2-6	interbedded ss/sh/ls/coal	1-100	79
6Da114	50-75	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	2-6	interbedded ss/sh/ls/coal	1-100	83
6Da115	50-75	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	2-6	interbedded ss/sh/ls/coal	1-100	77
6Da116	30-50	2-4	interbedded ss/sh/ls/coal	Sandy Loam	12-18	interbedded ss/sh/ls/coal	1-100	84
6Da117	30-50	2-4	interbedded ss/sh/ls/coal	Silty Loam	6-12	interbedded ss/sh/ls/coal	1-100	77
6Da118	30-50	2-4	interbedded ss/sh/ls/coal	Silty Loam	12-18	interbedded ss/sh/ls/coal	1-100	80
6Da119	30-50	2-4	interbedded ss/sh/ls/coal	Sandy Loam	18+	interbedded ss/sh/ls/coal	1-100	82
6Da120	50-75	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	6-12	interbedded ss/sh/ls/coal	1-100	79
6Da121	30-50	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	12-18	interbedded ss/sh/ls/coal	1-100	81
6Da122	30-50	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	2-6	interbedded ss/sh/ls/coal	1-100	93
6Da123	30-50	2-4	interbedded ss/sh/ls/coal	Clay Loam	12-18	interbedded ss/sh/ls/coal	1-100	73
6Da124	50-75	2-4	interbedded ss/sh/ls/coal	Silty Loam	2-6	interbedded ss/sh/ls/coal	1-100	71
6Da125	75-100	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	6-12	interbedded ss/sh/ls/coal	1-100	74
6Da126	30-50	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	18+	interbedded ss/sh/ls/coal	1-100	85
6Da127	50-75	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	12-18	interbedded ss/sh/ls/coal	1-100	71
6Da128	30-50	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	6-12	interbedded ss/sh/ls/coal	1-100	89
6Da129	30-50	2-4	interbedded ss/sh/ls/coal	Silty Loam	12-18	interbedded ss/sh/ls/coal	1-100	75
6Da130	30-50	2-4	interbedded ss/sh/ls/coal	Sandy Loam	18+	interbedded ss/sh/ls/coal	1-100	77
6Da131	30-50	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	18+	interbedded ss/sh/ls/coal	1-100	90
6Da132	30-50	2-4	interbedded ss/sh/ls/coal	Silty Loam	2-6	interbedded ss/sh/ls/coal	1-100	81
6Da133	75-100	0-2	interbedded ss/sh/ls/coal	Thin/Absent Gravel	6-12	interbedded ss/sh/ls/coal	1-100	66
6Da134	75-100	0-2	interbedded ss/sh/ls/coal	Thin/Absent Gravel	2-6	interbedded ss/sh/ls/coal	1-100	70
6Da135	50-75	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	12-18	interbedded ss/sh/ls/coal	1-100	77

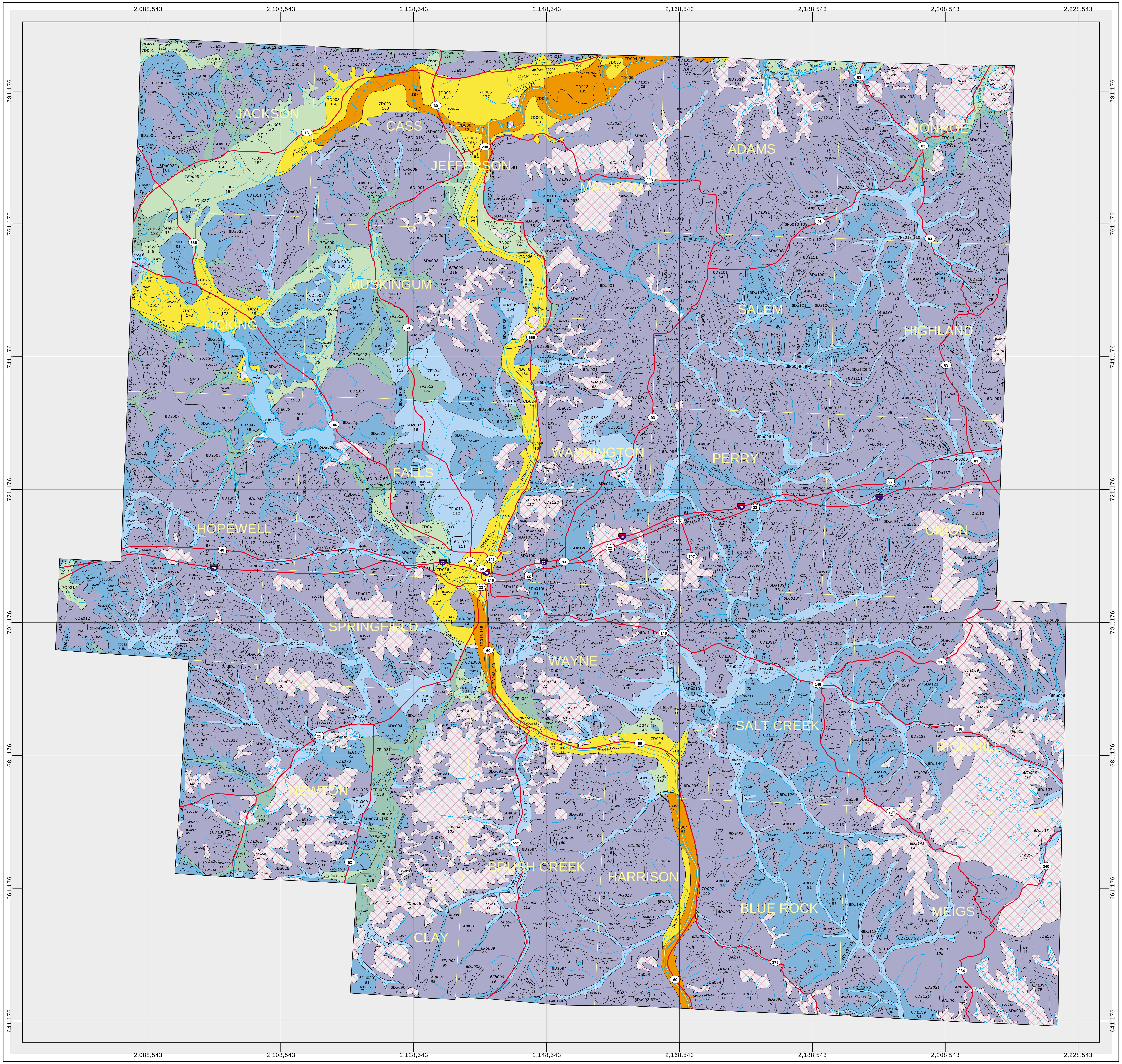
Setting	Depth To Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% Slope)	Vadose Zone Media	Hydraulic Conductivity	Rating
6Da136	75-100	0-2	interbedded ss/sh/ls/coal	Thin/Absent Gravel	18+	interbedded ss/sh/ls/coal	1-100	62
6Da137	30-50	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	18+	interbedded ss/sh/ls/coal	1-100	79
6Da138	30-50	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	12-18	interbedded ss/sh/ls/coal	1-100	87
6Da139	30-50	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	18+	interbedded ss/sh/ls/coal	1-100	84
6Da140	30-50	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	2-6	interbedded ss/sh/ls/coal	1-100	87
6Da141	75-100	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	18+	interbedded ss/sh/ls/coal	1-100	64
6Db01	30-50	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	interbedded ss/sh/ls/coal	1-100	99
6Dc001	30-50	2-4	interbedded ss/sh/ls/coal	Silty Loam	6-12	silt/clay	100-300	96
6Dc002	30-50	2-4	interbedded ss/sh/ls/coal	Silty Loam	2-6	silt/clay	100-300	100
6Dc003	50-75	2-4	interbedded ss/sh/ls/coal	Silty Loam	6-12	silt/clay	100-300	86
6Dc004	30-50	2-4	interbedded ss/sh/ls/coal	Silty Loam	2-6	silt/clay	1-100	94
6Dc005	50-75	2-4	interbedded ss/sh/ls/coal	Silty Loam	2-6	silt/clay	1-100	84
6Dc006	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	silt/clay	1-100	117
6Dc007	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	2-6	silt/clay	1-100	116
6Dc008	30-50	2-4	interbedded ss/sh/ls/coal	Silty Loam	6-12	silt/clay	1-100	90
6Dc009	15-30	2-4	interbedded ss/sh/ls/coal	Silty Loam	2-6	silt/clay	1-100	104
6Dc010	30-50	2-4	interbedded ss/sh/ls/coal	Silty Loam	2-6	silt/clay	1-100	91
6Dc011	75-100	2-4	interbedded ss/sh/ls/coal	Silty Loam	2-6	silt/clay	1-100	76
6Dc012	30-50	2-4	interbedded ss/sh/ls/coal	Silty Loam	6-12	silt/clay	1-100	87
6Dc013	15-30	2-4	interbedded ss/sh/ls/coal	Silty Loam	2-6	silt/clay	1-100	101
6Dc014	50-75	2-4	interbedded ss/sh/ls/coal	Silty Loam	2-6	silt/clay	1-100	81
6Dc015	50-75	2-4	interbedded ss/sh/ls/coal	Silty Loam	6-12	silt/clay	1-100	77
6Fa01	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	silt/clay	100-300	118
6Fa02	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	silt/clay	100-300	123

Setting	Depth To Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% Slope)	Vadose Zone Media	Hydraulic Conductivity	Rating
6Fb001	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	2-6	interbedded ss/sh/ls/coal	100-300	122
6Fb002	5-15	4-7	sand + gravel	Loam	2-6	sd + gvl w/ si + cl	100-300	137
6Fb003	15-30	4-7	interbedded ss/sh/ls/coal	Loam	2-6	interbedded ss/sh/ls/coal	100-300	124
6Fb004	30-50	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	interbedded ss/sh/ls/coal	1-100	102
6Fb005	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	interbedded ss/sh/ls/coal	100-300	118
6Fb006	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	interbedded ss/sh/ls/coal	1-100	112
6Fb007	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	interbedded ss/sh/ls/coal	100-300	115
6Fb008	30-50	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	interbedded ss/sh/ls/coal	100-300	108
6Fb009	30-50	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	interbedded ss/sh/ls/coal	1-100	99
6Fb010	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	interbedded ss/sh/ls/coal	1-100	109
6Fb011	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	2-6	interbedded ss/sh/ls/coal	1-100	111
7Aa01	30-50	2-4	interbedded ss/sh/ls/coal	Clay Loam	6-12	interbedded ss/sh/ls/coal	1-100	83
7Aa02	50-75	2-4	interbedded ss/sh/ls/coal	Clay Loam	12-18	interbedded ss/sh/ls/coal	1-100	71
7Aa03	50-75	2-4	interbedded ss/sh/ls/coal	Clay Loam	6-12	interbedded ss/sh/ls/coal	1-100	73
7Aa04	75-100	2-4	interbedded ss/sh/ls/coal	Clay Loam	6-12	interbedded ss/sh/ls/coal	1-100	68
7Bb01	30-50	4-7	sand + gravel	Clay Loam	2-6	sd + gvl w/ si + cl	100-300	115
7Bb02	15-30	4-7	interbedded ss/sh/ls/coal	Sandy Loam	2-6	sd + gvl w/ si + cl	1-100	120
7D001	5-15	7-10	sand + gravel	Silty Loam	0-2	sd + gvl w/ si + cl	300-700	155
7D002	15-30	7-10	sand + gravel	Silty Loam	0-2	sd + gvl w/ si + cl	700-1000	154
7D003	15-30	7-10	sand + gravel	Silty Loam	0-2	sd + gvl w/ si + cl	1000-2000	168
7D004	5-15	7-10	sand + gravel	Sandy Loam	0-2	sand + gravel	1000-2000	187
7D005	15-30	7-10	sand + gravel	Sandy Loam	0-2	sand + gravel	1000-2000	177
7D006	5-15	7-10	sand + gravel	Sandy Loam	0-2	sd + gvl w/ si + cl	1000-2000	182
7D007	15-30	7-10	sand + gravel	Silty Loam	0-2	sd + gvl w/ si + cl	300-700	145
7D008	15-30	7-10	sand + gravel	Thin/Absent Gravel	0-2	sd + gvl w/ si + cl	300-700	162

Setting	Depth To Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% Slope)	Vadose Zone Media	Hydraulic Conductivity	Rating
7D009	15-30	7-10	sand + gravel	Silty Loam	0-2	sd + gvl w/ si + cl	100-300	134
7D010	30-50	7-10	sand + gravel	Sandy Loam	2-6	sd + gvl w/ si + cl	100-300	132
7D011	30-50	4-7	sand + gravel	Silty Loam	6-12	sd + gvl w/ si + cl	100-300	111
7D012	15-30	7-10	sand + gravel	Silty Loam	2-6	sd + gvl w/ si + cl	300-700	142
7D013	15-30	7-10	sand + gravel	Thin/Absent Gravel	0-2	sd + gvl w/ si + cl	1000-2000	185
7D014	5-15	7-10	sand + gravel	Silty Loam	0-2	sd + gvl w/ si + cl	1000-2000	178
7D015	30-50	4-7	sand + gravel	Sandy Loam	6-12	sd + gvl w/ si + cl	100-300	115
7D016	5-15	7-10	sand + gravel	Silty Loam	0-2	sd + gvl w/ si + cl	300-700	153
7D017	15-30	7-10	sand + gravel	Sandy Loam	0-2	sd + gvl w/ si + cl	300-700	147
7D018	5-15	7-10	sand + gravel	Silty Loam	0-2	sd + gvl w/ si + cl	300-700	150
7D019	15-30	4-7	sand + gravel	Loam	0-2	sd + gvl w/ si + cl	300-700	134
7D020	15-30	4-7	sand + gravel	Clay Loam	0-2	sd + gvl w/ si + cl	300-700	130
7D021	30-50	4-7	sand + gravel	Silty Loam	2-6	silt/clay	300-700	116
7D022	15-30	4-7	sand + gravel	Shrink/Swell Clay	0-2	silt/clay	300-700	133
7D023	15-30	7-10	sand + gravel	Silty Loam	0-2	sd + gvl w/ si + cl	300-700	148
7D024	5-15	7-10	sand + gravel	Sandy Loam	0-2	sd + gvl w/ si + cl	700-1000	168
7D025	5-15	7-10	sand + gravel	Silty Loam	0-2	sd + gvl w/ si + cl	1000-2000	173
7D026	5-15	7-10	sand + gravel	Silty Loam	0-2	sd + gvl w/ si + cl	700-1000	164
7D029	30-50	4-7	sand + gravel	Clay Loam	2-6	silt/clay	700-1000	123
7D030	5-15	7-10	sand + gravel	Loam	0-2	sd + gvl w/ si + cl	300-700	157
7D031	5-15	7-10	sand + gravel	Clay Loam	0-2	sd + gvl w/ si + cl	300-700	153
7D032	5-15	4-7	sand + gravel	Silty Loam	0-2	silt/clay	100-300	128
7D033	15-30	7-10	sand + gravel	Silty Loam	0-2	sd + gvl w/ si + cl	700-1000	159
7D034	15-30	7-10	sand + gravel	Shrink/Swell Clay	0-2	silt/clay	1000-2000	169
7D035	30-50	7-10	sand + gravel	Silty Loam	0-2	sd + gvl w/ si + cl	300-700	138
7D036	30-50	7-10	sand + gravel	Sandy Loam	0-2	sd + gvl w/ si + cl	300-700	142
7D037	30-50	7-10	sand + gravel	Shrink/Swell Clay	0-2	silt/clay	300-700	139

Setting	Depth To Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% Slope)	Vadose Zone Media	Hydraulic Conductivity	Rating
7D038	15-30	7-10	sand + gravel	Shrink/Swell Clay	0-2	silt/clay	700-1000	155
7D039	5-15	7-10	sand + gravel	Sandy Loam	0-2	sd + gvl w/ si + cl	300-700	159
7D040	15-30	7-10	sand + gravel	Sandy Loam	2-6	sd + gvl w/ si + cl	300-700	148
7D041	15-30	7-10	sand + gravel	Thin/Absent Gravel	0-2	sd + gvl w/ si + cl	300-700	157
7D042	15-30	7-10	sand + gravel	Thin/Absent Gravel	0-2	sd + gvl w/ si + cl	700-1000	171
7D043	5-15	7-10	sand + gravel	Thin/Absent Gravel	0-2	sd + gvl w/ si + cl	1000-2000	190
7D044	15-30	4-7	sand + gravel	Silty Loam	0-2	silt/clay	300-700	132
7D045	15-30	7-10	sand + gravel	Sandy Loam	0-2	sd + gvl w/ si + cl	300-700	149
7D046	15-30	7-10	sand + gravel	Thin/Absent Gravel	0-2	sd + gvl w/ si + cl	300-700	160
7D047	15-30	4-7	sand + gravel	Thin/Absent Gravel	0-2	sd + gvl w/ si + cl	300-700	146
7D048	15-30	4-7	sand + gravel	Thin/Absent Gravel	2-6	sd + gvl w/ si + cl	300-700	148
7D049	15-30	7-10	sand + gravel	Sandy Loam	0-2	sd + gvl w/ si + cl	700-1000	158
7Ec01	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	2-6	silt/clay	100-300	122
7Fa001	5-15	4-7	sand + gravel	Silty Loam	0-2	sd + gvl w/ si + cl	300-700	142
7Fa002	5-15	4-7	sand + gravel	Silty Loam	2-6	sd + gvl w/ si + cl	100-300	135
7Fa003	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	2-6	silt/clay	100-300	122
7Fa004	15-30	4-7	sand + gravel	Silty Loam	2-6	silt/clay	100-300	125
7Fa005	5-15	4-7	sand + gravel	Silty Loam	2-6	silt/clay	100-300	135
7Fa006	30-50	4-7	interbedded ss/sh/ls/coal	Silty Loam	6-12	interbedded ss/sh/ls/coal	100-300	106
7Fa007	5-15	4-7	sand + gravel	Silty Loam	0-2	silt/clay	100-300	136
7Fa008	15-30	4-7	sand + gravel	Silty Loam	0-2	silt/clay	100-300	126
7Fa009	15-30	4-7	sand + gravel	Silty Loam	0-2	sd + gvl w/ si + cl	300-700	132
7Fa010	15-30	4-7	sand + gravel	Silty Loam	2-6	sd + gvl w/ si + cl	300-700	131
7Fa011	30-50	4-7	sand + gravel	Silty Loam	0-2	sd + gvl w/ si + cl	300-700	122
7Fa012	15-30	4-7	sand + gravel	Silty Loam	0-2	silt/clay	300-700	124
7Fa013	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	silt/clay	1-100	112

Setting	Depth To Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% Slope)	Vadose Zone Media	Hydraulic Conductivity	Rating
7Fa014	30-50	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	silt/clay	1-100	102
7Fa015	5-15	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	silt/clay	100-300	128
7Fa016	15-30	4-7	sand + gravel	Sandy Loam	0-2	silt/clay	300-700	136
7Fa017	15-30	4-7	sand + gravel	Silty Loam	0-2	silt/clay	300-700	127
7Fa018	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	silt/clay	1-100	117
7Fa019	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	2-6	sd + gvl w/ si + cl	1-100	116
7Fa020	15-30	4-7	sand + gravel	Sandy Loam	0-2	sd + gvl w/ si + cl	300-700	133
7Fa021	15-30	4-7	sand + gravel	Silty Loam	0-2	silt/clay	300-700	129
7Fa022	30-50	4-7	sand + gravel	Thin/Absent Gravel	0-2	sd + gvl w/ si + cl	300-700	136
7Fa023	15-30	4-7	sand + gravel	Shrink/Swell Clay	0-2	silt/clay	300-700	130
7Fa024	5-15	4-7	sand + gravel	Silty Loam	0-2	sd + gvl w/ si + cl	300-700	134
7Fa025	5-15	4-7	sand + gravel	Sandy Loam	0-2	sd + gvl w/ si + cl	300-700	138
7Fa026	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	silt/clay	1-100	109
7Fa027	15-30	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	0-2	silt/clay	1-100	101
7Fa028	30-50	4-7	sand + gravel	Silty Loam	0-2	sd + gvl w/ si + cl	300-700	119
7Fa030	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	2-6	silt/clay	1-100	111
7Fa031	30-50	4-7	interbedded ss/sh/ls/coal	Shrink/Swell Clay	0-2	silt/clay	1-100	105
7Fa032	30-50	4-7	interbedded ss/sh/ls/coal	Shrink/Swell Clay	6-12	silt/clay	1-100	100
7Fa033	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	2-6	silt/clay	100-300	117
7G01	30-50	2-4	interbedded ss/sh/ls/coal	Silty Loam	6-12	interbedded ss/sh/ls/coal	100-300	91
7G02	30-50	4-7	interbedded ss/sh/ls/coal	Clay Loam	2-6	till	100-300	105



Ground Water Pollution Potential of Muskingum County

by
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Ohio Department of Natural Resources

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

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

Description of Map Symbols

Hydrogeologic Region → 7D24 ← Hydrogeologic Setting
170 ← Relative Pollution Potential

Legend

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

- Roads
- Streams
- Lakes
- Townships

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

N

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

0 1 2 3 4 5
Miles

0 1 2 4 6 8
Kilometers

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