GROUND WATER POLLUTION POTENTIAL OF TUSCARAWAS COUNTY, OHIO

BY

MICHAEL P. ANGLE AND JASON BAKER

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ABSTRACT

A ground water pollution potential map of Tuscarawas County has been prepared using the DRASTIC mapping process. The DRASTIC system consists of two major elements: the designation of mappable units, termed hydrogeologic settings, and the superposition of a relative rating system for pollution potential.

Hydrogeologic settings incorporate hydrogeologic factors that control ground water movement and occurrence including depth to water, net recharge, aquifer media, soil media, topography, impact of the vadose zone media, and hydraulic conductivity of the aquifer. These factors, which form the acronym DRASTIC, are incorporated into a relative ranking scheme that uses a combination of weights and ratings to produce a numerical value called the ground water pollution potential index. Hydrogeologic settings are combined with the pollution potential indexes to create units that can be graphically displayed on a map.

Ground water pollution potential analysis in Tuscarawas County resulted in a map with symbols and colors, which illustrate areas of varying ground water pollution potential indexes ranging from 53 to 202.

Tuscarawas County lies almost entirely within the Nonglaciated Central hydrogeologic setting. The extreme northwestern corner of the county (northwestern Wayne Township) is within the Glaciated Central hydrogeologic setting. The buried valley underlying the present main channel of the Tuscarawas River south of Dover contains sand and gravel outwash, which is capable of yielding up to 500 gallons per minute (gpm) from properly designed, large diameter wells. Similar yields are obtained from buried valleys underlying Sugar Creek northwest of Dover, and portions of Sandy Creek east of Bolivar. Yields of 25-100 gpm are obtained from the margins of the buried valley underlying the Tuscarawas River and Sugar Creek. Yields obtained from wells completed in the buried valleys underlying Conotton Creek and Stillwater Creek average from 5 to 25 gpm. Smaller tributaries contain only thin, fine-grained alluvial/lacustrine deposits commonly yielding less than 5 gpm.

Interbedded dirty sandstones, shales, thin limestones, coals, and claystones of the Pennsylvanian System and interbedded sandstones and shales of the Mississippian System comprise the aquifer for the majority of Tuscarawas County. Wells developed from highly fractured sandstones and shales of the Mississippian and Pennsylvanian Pottsville Group yield up to 50 gpm in northwestern Tuscarawas County. Elsewhere in the county, these units typically yield 10 to 25 gpm. Wells developed in the Pennsylvanian Allegheny Group typically yield from 5 to 10 gpm. The Pennsylvanian Conemaugh Group contains poor aquifers with yields 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 Tuscarawas 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 area, or to assist in protection, monitoring, and clean-up efforts.

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The preparation of the Tuscarawas County Ground Water Pollution Potential report and map involved the contribution and work of a number of individuals in the Division of Water. Grateful acknowledgement is given to the following individuals for their technical review and map production, text authorship, report editing, and preparation:

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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; 10,500 of these wells exist in Tuscarawas 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 Tuscarawas 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 Tuscarawas 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.

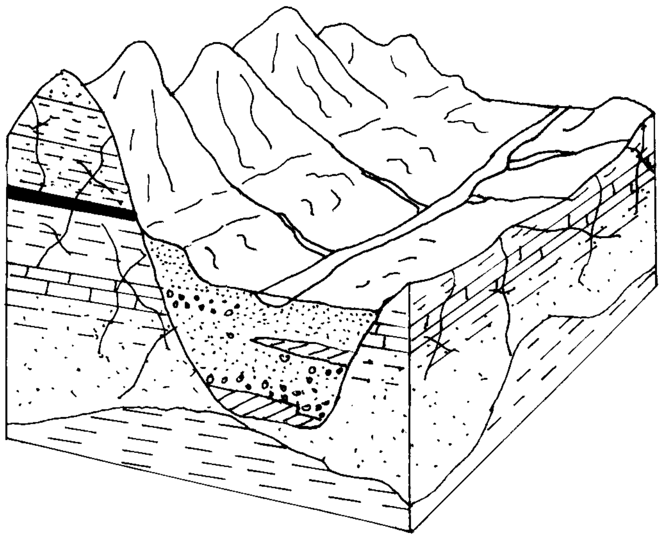
Depth to water is considered to be the depth from the ground surface to the water table in unconfined aquifer conditions or the depth to the top of the aquifer under confined aquifer conditions. The depth to water determines the distance a contaminant would have to travel before reaching the aquifer. 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.

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



7D Buried Valley

This hydrogeologic setting is widespread through Tuscarawas County. All of the major trunk streams and many modern tributaries overlie buried valley deposits. The setting is easy to distinguish from the surrounding uplands; it is characterized by broad, flat-lying floodplains and gently sloping terraces. Depth to water is typically less than 30 feet, and is less than 15 feet when immediately adjacent to the primary trunk streams such as the Tuscarawas River, Sandy Creek, Sugar Creek, etc. Aquifers are composed of variable thicknesses of sand and gravel interbedded with finer-grained alluvium 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 the Tuscarawas River, Sandy Creek, and Sugar Creek. Along the margins of these valleys and tributaries, the outwash tends to be interbedded with finer-grained materials and yields range from 25 to 100 gpm. Some valleys, including Conotton Creek and Stillwater Creek, 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.

GWPP index values for the hydrogeologic setting of Buried Valley range from 119 to 202, with the total number of GWPP index calculations equaling 70.

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

infiltrate into the subsurface. Topography also affects soil development and often can beused 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	

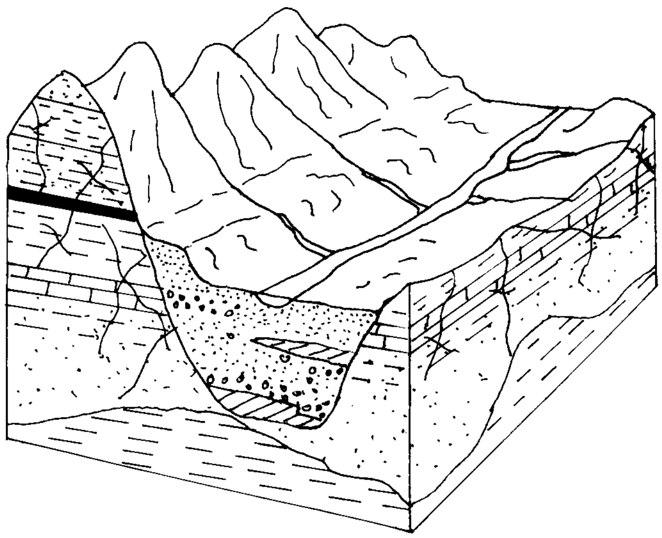
Table 8. Ranges and ratings for hydraulic conductivity

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 Tuscarawas 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 167. 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 Tuscarawas County produces settings with a wide range of vulnerability to ground water contamination. Calculated pollution potential indexes for the 7 settings identified in the county range from 53 to 202.

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 Tuscarawas 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 Tuscarawas County is included with this report.



SETTING 7D1		GENERAL		
FEATURE	**RANGE**	**WEIGHT**	**RATING**	**NUMBER**
Depth to Water	30-50	5	5	25
Net Recharge	7-10	4	8	32
Aquifer Media	Sand & Gravel	3	8	24
Soil Media	Sand	2	9	18
Topography	2-6%	1	9	9
Impact of Vadose Zone	Sand & Gravel w/Significant Silt & Clay	5	7	35
Hydraulic Conductivity	1000-2000	3	8	24
		DRASTIC	INDEX	167

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
167 - defines the relative pollution potential

Here the first number (**7**) refers to the major hydrogeologic region and the upper case letter (**D**) refers to a specific hydrogeologic setting. The following number (**1**) references a certain set of DRASTIC parameters that are unique to this setting and are described in the corresponding setting chart. The second number (**167**) 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 TUSCARAWAS COUNTY

Demographics

Tuscarawas County occupies approximately 569 square miles in northeastern Ohio (Figure 3). Tuscarawas County is bounded to the northeast by Carroll County, to the southeast by Harrison County, to the south by Guernsey County, to the southwest by Coshocton County, to the northwest by Holmes County, and to the north by Stark County.

The approximate population of Tuscarawas County, based upon 1998 estimates, is 88,660 (Department of Development, Ohio County Profiles, 1999). New Philadelphia is the largest community and the county seat. Agriculture accounts for roughly 50 percent of the land usage in Tuscarawas County. Woodlands, industry, and mining are the other major land uses in the county. Residential growth is increasing, both in the New Philadelphia-Dover area, and along Interstate Rt-77 adjacent to Stark County. More specific information on land usage can be obtained from the Ohio Department of Natural Resources, Division of Real Estate and Land Management (REALM), Resource Analysis Program (formerly OCAP).

Climate

The *Hydrologic Atlas for Ohio* (Harstine, 1991) reports an average annual temperature of approximately 50 degrees Fahrenheit for Tuscarawas County. The average temperatures increase slightly towards the south. Harstine (1991) shows that precipitation averages 38 inches per year for the county, with precipitation increasing towards the south and east. The mean annual precipitation for New Philadelphia is 39 inches per year, based on a twenty-year (1961-1980) period (Owenby and Ezell, 1992). The mean annual temperature at New Philadelphia for the same twenty-year period is 49.6 degrees Fahrenheit (Owenby and Ezell, 1992).

Physiography and Topography

The vast majority of Tuscarawas County lies within the Unglaciated Allegheny Plateau section of the Appalachian Plateau Province (Frost, 1931 and Fenneman, 1938). The extreme northwestern corner of the county (northwestern Wayne 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. The overall relief increases toward the south. Floodplains of the Muskingum River and its major tributaries, including Conotton Creek, Stillwater Creek, Sandy Creek, and Sugar Creek, are relatively broad and flat lying. These valleys stand out in contrast from the surrounding steep uplands.

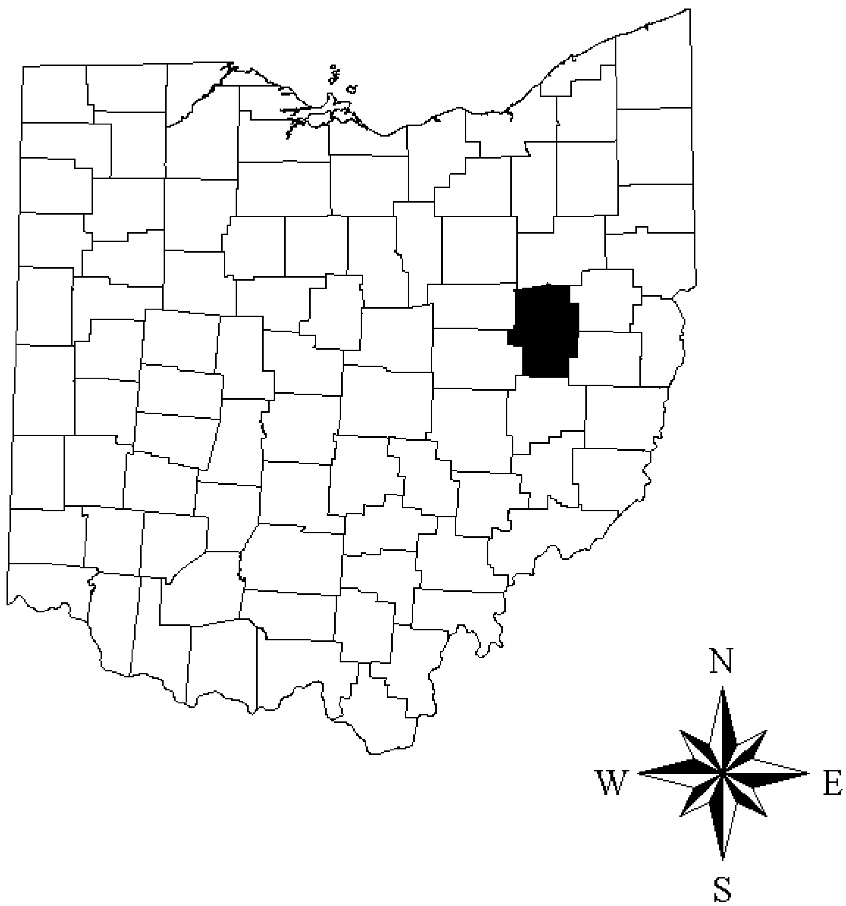


Figure 3. Location of Tuscarawas County, Ohio.

The highest point in the county is approximately 1,340 feet above sea level, the lowest point, about 795 feet, is along the Tuscarawas River near Newcomerstown. Total relief is over 500 feet.

Modern Drainage

The Tuscarawas River and its tributaries drain the vast majority of Tuscarawas County. Extreme southwestern Tuscarawas County is drained by tributaries of Wills Creek, which eventually empties into the Muskingum River south of the City of Coshocton. Sugar Creek is an important tributary draining the northwestern part of the county. Sandy Creek, another tributary, drains the far northeastern corner of Tuscarawas County. Conotton Creek and Stillwater Creek are the two main tributaries that drain the eastern half of the county. The central and western portion of the county is drained by the main trunk of the Tuscarawas River, along with many very minor tributaries.

Pre- and Inter-Glacial Drainage Changes

The drainage patterns of Tuscarawas County have changed significantly as a result of the multiple glaciations. The drainage changes are complex and not yet fully understood. More research and data are necessary in both Tuscarawas County and adjacent counties. Particularly, well log data for deeper wells that penetrate the entire drift thickness would be helpful in making interpretations.

Stout et al. (1943) and Lamborn (1956) thoroughly discuss the ancestral drainage history of Tuscarawas County. Prior to the glaciation, the northerly-flowing Dover River primarily drained Tuscarawas County (Figure 4). The Dover River roughly followed the course of Stillwater Creek to Midvale and then followed the course of present-day Tuscarawas River northward. North of New Philadelphia, the Dover River followed the course of modern Sugar Creek to Brewster. The Dover River then extended slightly more northeastward, passing through Canton and Akron. North of Akron, the Dover River continued a course similar to the modern Cuyahoga River. Zoar Creek, a major tributary of the Dover River, flowed northwestward, approximately following present Conotton Creek and the portion of the Tuscarawas River northwest of Zoar Station. Sandyville Creek, a westerly-flowing tributary to Zoar Creek, closely followed the course of modern Sandy Creek. There was an important local drainage divide in southwestern Tuscarawas County nearby present-day Stone Creek. The divide consisted of a resistant bedrock ridge or col; southwest of this col drainage was to the west. Newcomerstown Creek drained the area west of this col, and eventually merged with the Groveport River near the present city of Newark. The Groveport River was a major tributary of the Teays River System (Stout et al., 1943 and Lamborn, 1956).

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.,

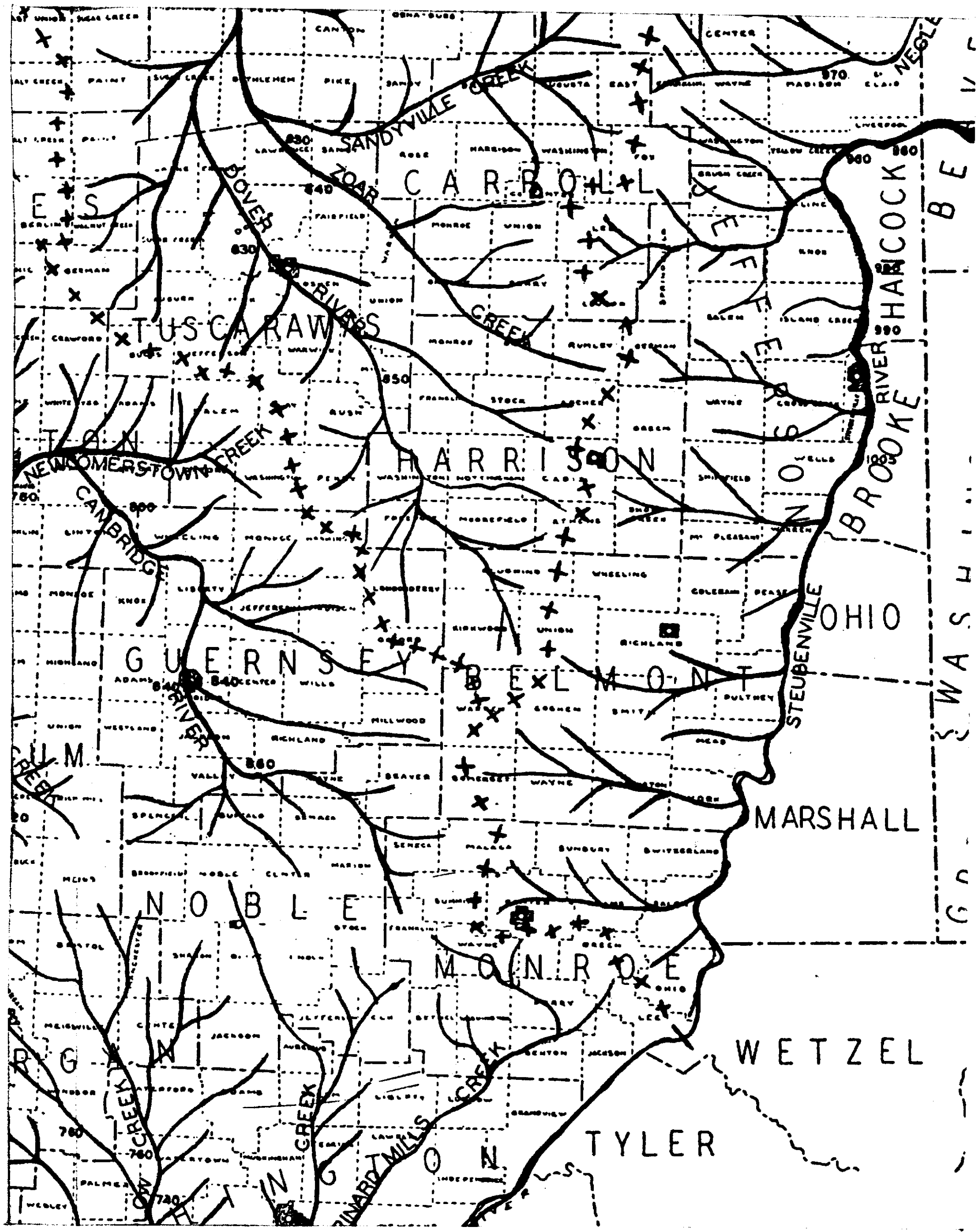


Figure 4. Pre-glacial Teays Stage drainage (after Stout et al., 1943).

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 this increased downcutting. In Tuscarawas County, the northerly-flowing Dover River was similarly blocked by the advancing ice sheet (Stout et al., 1943 and Lamborn (1956). Water in the blocked river valley rose and breached the col near present-day Port Washington. Eventually, a new trunk stream referred to as the Newark River down-cut and its headwaters eroded eastward, replacing Newcomerstown Creek as the principal drainage system of this area. The Newark River extended northward into Stark County. Urichsville Creek was a northerly flowing tributary of the Newark River that occupied the portion of the Dover River south of New Philadelphia and lower Stillwater Creek (Stout et al., 1943 and Lamborn, 1956). Stout et al. (1943) referred to the deepened valley occupying the former Zoar Creek Valley as Sherodsville Creek. Lamborn (1956) suggested that the Newark River caused the valley to be entrenched or deepened over 175 feet below present stream levels in the vicinity of Dover and southwards.

The Illinoian ice advance brought further changes to the drainage systems (Figure 6). Opinions as to the nature of drainage directions 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. Drainage to the north was possible because there was no blockage by advancing Illinoian ice at this time. Stout et al. (1943) referred to this northerly flowing trunk stream as the Massillon River. Bolivar Creek and Tracy Creek were northerly flowing tributaries that occupied the former valleys of Sherodsville Creek and Urichsville Creek respectively.

Lamborn (1956) and DeLong and White (1961) proposed that Illinoian ice did advance into northeastern Ohio and blocked drainage northward. Drainage was still primarily to the southwest through the Newark River. Ice-blockage near the city of Newark 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 and new drainage ways were established along the Licking River and Muskingum River.

The most recent ice advance, the Wisconsinan, brought further drainage changes to Tuscarawas County (Lamborn, 1956 and DeLong and White, 1963). The advancing ice overran the headwaters of the Newark River north of the modern Tuscarawas County-Stark County boundary. The abundant meltwater deposited coarse outwash in ancestral Sugar Creek and Tuscarawas River south of Dover. Sandy Creek received abundant meltwater from the Grand River Lobe in southeastern Stark County and Columbiana County (DeLong and White, 1963 and White, 1982). The meltwater deposited relatively thick sequences of coarse outwash. The Wisconsinan ice advances blocked northerly flowing Bolivar Creek (formerly Zoar Creek). The ponded water rose and eventually cut a new outlet to the

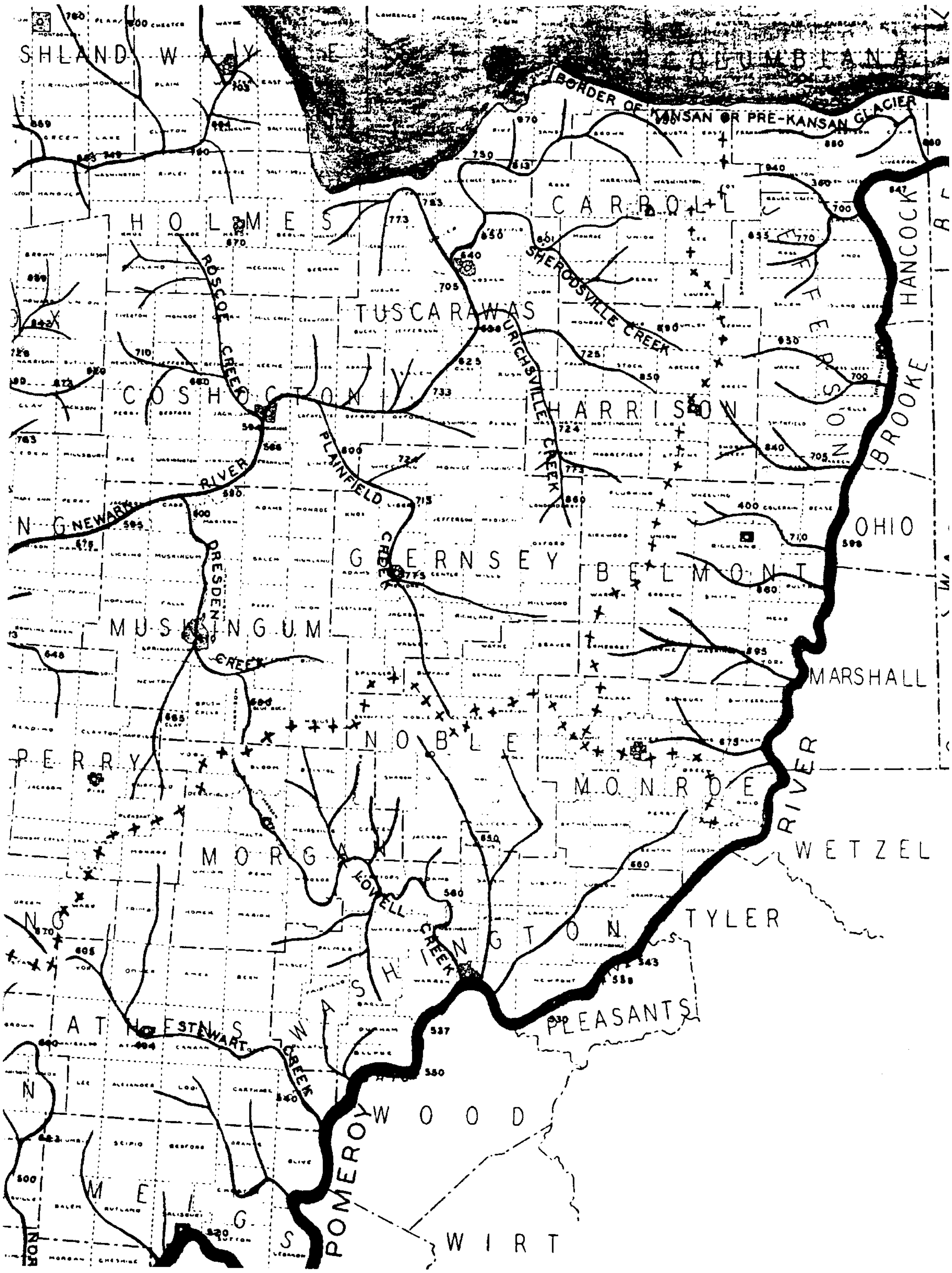


Figure 5. Deep Stage drainage (after Stout et al., 1943).

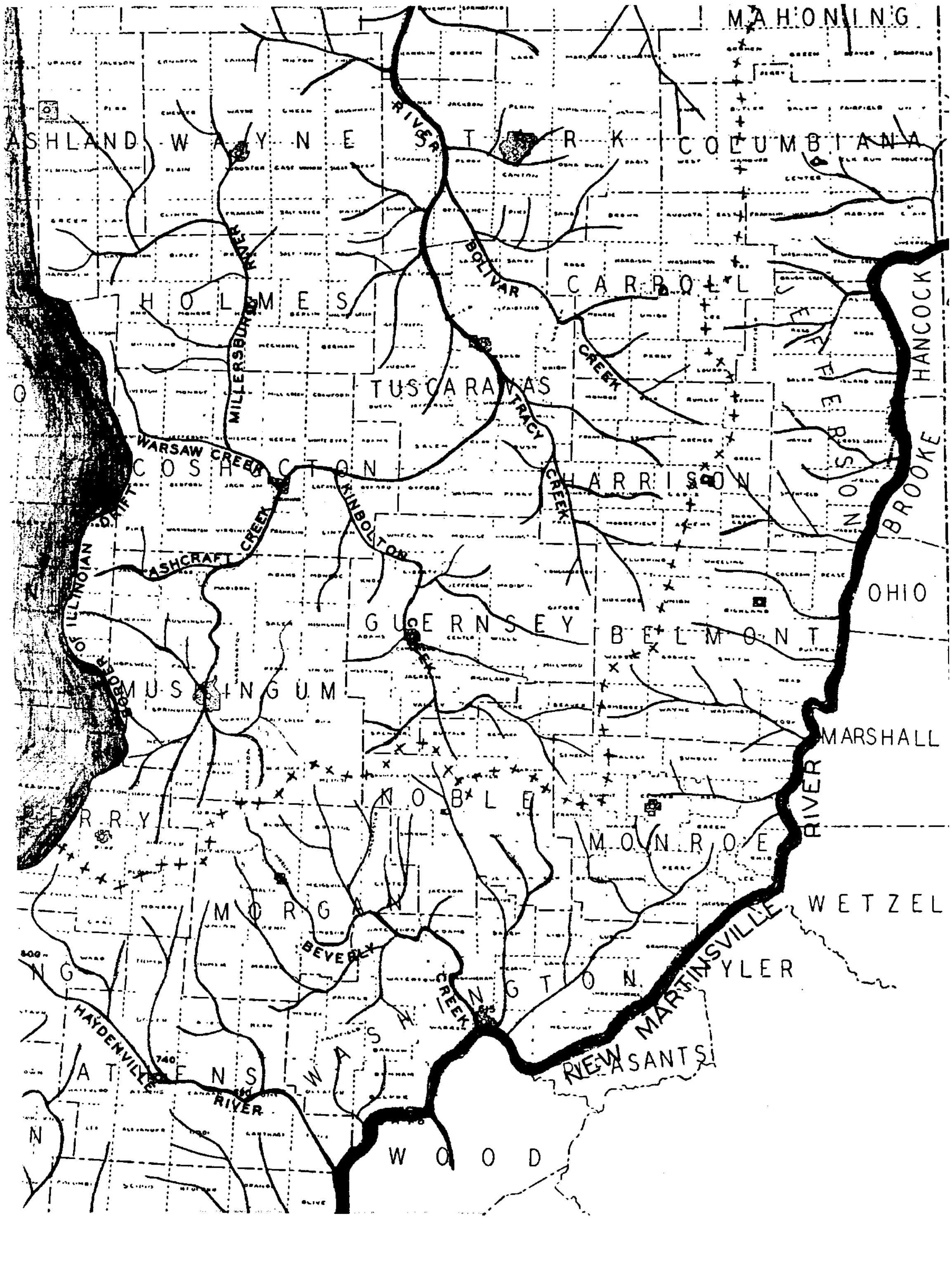


Figure 6. Illinoian-age drainage (after Stout et al., 1943).

southwest at Zoar Station (Lamborn, 1956). This allowed for southerly drainage of the upper headwaters of the Tuscarawas River and Conotton Creek meltwater carrying coarser sediments flowed southwestward toward Dover. The mouth of Conotton Creek may have been partially blocked and localized ponding occurred in lower Conotton Creek and Indian Fork. The mouth of ancestral Stillwater Creek (formerly Tracey Creek) may have also have been partially blocked resulting in the deposition of fine-grained lacustrine sediments in this valley.

Glacial Geology

Ice from the Killbuck Lobe during the most recent (late Wisconsinan) ice-advance entered the extreme northwestern corner of Tuscarawas County. The ice deposited a moderately sandy to clayey, highly weathered till which thinly mantled the local uplands (DeLong and White, 1963; Goldthwait et al., 1961, and White, 1982).

The majority of the glacially-related deposits are limited to the ancestral stream channels (Cummins and Sanderson, 1947 and Lamborn, 1956)). 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 (lake) 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. Streams, which 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.

Coarse-grained outwash deposits primarily occur in the main trunk of the Tuscarawas River Valley from Dover southwestward into Coshocton County, in the Tuscarawas River Valley north of Bolivar into Stark County, and along Sandy Creek. Finer-grained deposits are more prevalent in the portions of the Tuscarawas River between Bolivar and Dover, along Conotton Creek, along Stillwater Creek, and along the numerous other smaller tributaries (Cummins and Sanderson, 1947: Lamborn, 1956; DeLong and White, 1963; and Barber, 1989).

Bedrock Geology

Bedrock exposed at the surface in Tuscarawas County belongs to the Pennsylvanian System. Deeper wells, especially in northern and western Tuscarawas County, also encounter rocks of the Mississippian System. Table 9 summarizes the bedrock stratigraphy found in Tuscarawas County. Lamborn (1956) and Cummins and Sanderson, (1947) give a thorough review of the bedrock stratigraphy of Tuscarawas County. The ODNR, Division of Geological Survey, has Open-File Reconnaissance Bedrock Geological Maps completed on a1:24,000 scale USGS topographic map base available for the entire county.

Table 9. Bedrock stratigraphy of Tuscarawas County

System	Group/Formation (Symbol)	Lithologic Description
Pennsylvanian	Pennsylvanian Undifferentiated, i.e. Conemaugh, Monongahela Fms. (Pu)	Interbedded dirty sandstones, shales, and siltstones with thin coal, limestone, and clay layers. Poor aquifer with yields of less than 5 gpm. Found on ridge tops in southern and eastern Tuscarawas County.
	Allegheny and Pottsville Groups (Pap) Allegheny-Upper Pottsville Groups (Pa-up)	Gray to black interbedded sandstone, siltstone and shale, with thin layers of cal, clay, and limestone. May include the Homewood Sandstone. Poor to moderate aquifer with yields from 0 to 25 gpm. Widespread throughout Tuscarawas County.
	Massillon through Sharon Formations (Pm-s)	Coarse to medium-grained cross-bedded sandstones. Gray-white sandstones may have conglomerate zones. May also contain thin shale and coal layers. Good aquifer with yields ranging from 5 to 100 gpm. Limited to northern third of county.
Mississippian	Logan and Black Hand Formations (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 25 to 100 gallons per minute. Limited to northwest corner of Tuscarawas County.
	Cuyahoga Group (Mcg)	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 5 to 25 gallons per minute. Limited to the northeast corner of the county.

Interbedded sandstones and shales of the Mississippian age are encountered in the subsurface of much of western and northern Tuscarawas County. Yields are primarily obtained from sandstones of the Black Hand Formation of the Cuyahoga Group or Logan Formation (Cummins and Sanderson, 1947 and Lamborn, 1956). Drillers commonly refer to these sandstones as the “Big Injun”. Farther to the southeast in Tuscarawas County, these formations become deeper and tend to contain salt or brackish water, gas, and oil. The oldest rocks exposed in Tuscarawas County are part of the Pottsville Group and crop out at the base of stream exposures through much of northern and western Tuscarawas County, and along ridge tops in northwestern Tuscarawas County. Rocks of the Pottsville Group include interbedded dirty sandstones, shales, siltstones, and thin coals. The Massillon Sandstone and Homewood Sandstone are the primary water producers of the Pottsville Group. Rocks of the Allegheny Group are exposed in much of the western part of the county and in deeper stream valleys in central and eastern Tuscarawas 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 Conemaugh Group are found in most of southern and eastern Tuscarawas County. These rocks include interbedded dirty sandstones, shales, and minor limestones.

Weedman (1990) provides an excellent account of the complex depositional environments that 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 a "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 Tuscarawas County is obtained from both unconsolidated (glacial-alluvial) and consolidated (bedrock) aquifers. Glacial aquifers are primarily associated with the buried valleys and thicker alluvial deposits.

Yields up to 500 (gpm) are obtainable from the coarse, well-sorted sand and gravel outwash deposits in the Tuscarawas River Valley south of Dover, Sugar Creek northwest of

Dover, and portions of Sandy Creek east of Bolivar (Cummins and Sanderson, 1947, Barber, 1989, and ODNR, Div. of Water Open File, Glacial State Aquifer Map). 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 sustainable high yields capable from these larger diameter wells. Smaller diameter wells should be suitable for serving domestic/farm needs within this aquifer. Yields of 25 to 100 gpm are obtained from wells drilled along the margins of the Sugar Creek-Tuscarawas River buried valley and tributaries. Thin lenses of sand and gravel interbedded with finer-grained materials in the buried valleys underlying Conotton Creek and Stillwater Creek yield 5 to 25 gpm. Fine-grained deposits located in minor tributaries of Stillwater Creek in southeastern Tuscarawas County typically are thin and fine-grained and constitute a very marginal aquifer (Cummins and Sanderson, 1947; Barber, 1989; 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 sand and gravel lenses are present can produce yields up to 10 gpm. (Cummins and Sanderson, 1947; Barber, 1989; 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. Wells developed in some highly-fractured zones in the Mississippian Black Hand Sandstone and the Massillon Sandstone Formation of the Pottsville Group have yields ranging from 25 to 100 gpm in northwestern Tuscarawas County (Barber, 1989). Yields ranging from 10 to 25 gpm are common for other areas of interbedded sandstones and shales of the Mississippian System and Pottsville Group (Cummins and Sanderson, 1947 and Barber, 1989). 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 (Barber, 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 typically have meager yields averaging less than 3 gpm (Barber, 1989 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, which 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 valleys 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 Tuscarawas 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 Tuscarawas County. Delineations of mined areas were made using information from the *Soil Survey of Tuscarawas County* (Waters and Roth, 1986), abandoned underground mine maps (ODNR, Division of Geological Survey, open file maps), and the Morgan 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 10,500 water well log records are on file for Tuscarawas County. Data from roughly 5,000 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 *Water Resources of Tuscarawas County* (Cummins and Sanderson, 1947) and the *Ground Water Resources of Tuscarawas County* (Barber, 1989) provided generalized depth to water information throughout the county. Depth to water trends mapped in adjoining Stark County (Williams, 1991) and Coshocton County (Spahr, 1995) were used as a guideline. Topographic and geomorphic trends were utilized in areas where other sources of data were lacking.

Depths to water of 0 to 5 feet (DRASTIC rating = 10) were utilized for limited portions of tributaries to Sugar Creek, which contained predominantly flowing or nearly flowing wells. Depths to water of 5 to 15 feet (9) were typical of areas immediately adjacent to the Tuscarawas 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. 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.

Recharge values greater than 10 inches per year (9) were utilized for limited portions of the trunk valley of Sugar Creek and the Tuscarawas River in the Dover – New Philadelphia region. Values of 7 to 10 inches per year (8) were assigned to Sugar Creek, Sandy Creek east of Bolivar, and the main trunk of the Tuscarawas River south of Dover. These areas contain highly permeable soils, vadose, and aquifer materials, have shallow depths to water, gentle slopes, and surficial streams. These areas 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 southeastern Tuscarawas County. These area have very great depths to water, soils are thin or absent and slopes are very steep which contribute to very high run-off, and the rocks are very low permeability units of the Conemaugh Group.

Aquifer Media

Information on aquifer media was obtained from the reports of Stout et al. (1943), Cummins and Sanderson (1947), Lamborn (1958), Kaser (1960), White (1982) and Barber (1989). Mapping in adjoining Coshocton County (Spahr, 1995) and Stark County (Williams, 1991) proved useful as a guideline for evaluating aquifers. Open File Bedrock Reconnaissance Maps and Open File Bedrock Topography Maps, based upon U.S.G.S. 7-1/2 minute topographic maps from the ODNR, Division of Geological Survey proved helpful. 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.

An aquifer rating of (8) was designated for the high-yielding sand and gravel outwash deposits underlying the Tuscarawas River Valley south of Dover, Sugar Creek northwest of Dover, and Sandy Creek east of Bolivar. An aquifer rating of (7) was assigned to thinner, less continuous sand and gravel outwash deposits associated with tributaries of Sandy Creek, Sugar Creek, and the Tuscarawas River. An aquifer rating of (6) was used for some thinner sand and gravel deposits associated with tributaries and margins of the Tuscarawas River, Sandy Creek, and South Fork of Sugar Creek. Aquifer ratings of (5) and (6) were used for the thin sand and gravel lenses interbedded with thicker, fine-grained lacustrine and alluvial deposits in Conotton Creek and Stillwater Creek.

An aquifer rating of (6) was assigned to limited areas of the Massillon Sandstone-Pottsville Group adjacent to Stark County. An aquifer rating of (5) was utilized for interbedded sandstones and shales of the Mississippian Black Hand and Pennsylvanian Pottsville Group in western and northern Tuscarawas County. An aquifer rating of (4) was designated for the interbedded dirty sandstones, shales, thin limestones, and coals of the Allegheny Group in central Tuscarawas County. An aquifer rating of (3) was assigned to the interbedded dirty sandstones, shales, claystones, and limestones of the Conemaugh Group in eastern and southern Tuscarawas County.

Soils

Soils were mapped using the data obtained from the *Soil Survey of Tuscarawas County* (Waters and Roth, 1986). 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 Tuscarawas 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 Tuscarawas County.

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) for limited areas of the Tuscarawas River and Sandy Creek. Shrink-swell clays (7) were rated for upland areas having very clayey shale and mudstone bedrock residuum. Shrink-swell clay (7) was also evaluated for areas containing dense, clayey lacustrine sediments at the surface. Sandy loams (6) were selected for outwash-rich areas of the Tuscarawas River, Sugar Creek, Sandy Creek, Conotton Creek, and Stillwater Creek. Sandy loam soils (6) were also selected for steep, residual sandstone ridges throughout the county. Loam soils (5) were designated for coarser alluvial soils found in tributaries to the Tuscarawas River and Sugar Creek. Loam soils (5) were also used for bedrock slopes containing residuum from highly variable bedrock lithologies. 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. Clay loam (3) soils were evaluated for areas with fine-grained bedrock residuum. Clay loam soils (3) were also designated for the small area of glacial till found in the extreme northwest corner of the county.

Certain soils in Tuscarawas 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 Tuscarawas County* (Waters and Roth, 1986). 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.

Table 12. Tuscarawas County soils

Soil Name	Parent Material or Setting	DRASTIC Rating	Soil Media
Berks	Shale bedrock uplands	10	Thin or absent
Bethesda	Mine spoils	NR	
Bogart Variant	Outwash over lacustrine	7	Shrink/swell clay
Canadice	Lacustrine	7	Shrink/swell clay
Canadea	Lacustrine	7	Shrink/swell clay
Canfield*	Till with fragipan	3	Clay loam
Chili	Outwash	6	Sandy loam
Conotton	Outwash	6	Sandy loam
Coshocton	Residuum	3	Clay loam
Coshocton-Guernsey	Fine-grained bedrock	7	Shrink/swell clay
Elkinsville	Alluvium	4	Silty loam
Fitchville	Lacustrine, slack water	4	Silty loam
Glenford	Lacustrine, slack water	4	Silty loam
Guernsey	Fine-grained bedrock	7	Shrink/swell clay
Hazleton	Sandstone residuum	6	Sandy loam
Keene	Weathered siltstone	4	Silty loam
Linwood	Bogs, depressions	8	Peat
Melvin	Alluvium	4	Silty loam
Morristown	Bedrock	3	Clay loam
Nolin	Coarse alluvium over outwash	5	Loam
Orrville	Coarse alluvium	5	Loam
Plainfield	Outwash	9	Sand
Rigley	Sandstone regolith	6	Sandy loam
Rush	Coarse alluvium, outwash	6	Sandy loam
Sebring	Slack water	4	Silty loam
Shinrock	Fine lacustrine, slack water	3	Clay loam
Sparta	Outwash	9	Sand
Tioga	Outwash	6	Sandy loam
Upshur	Weathered shale	7	Shrink/swell clay
Weinbach	Old alluvium	4	Silty loam
Westmoreland	Bedrock residuum	4	Silty loam
Wheeling	Outwash terraces	6	Sandy loam

* denotes soil containing fragipan

Impact of the Vadose Zone Media

Information on vadose zone media was obtained from the reports of Stout et al. (1943), Cummins and Sanderson (1947), Lamborn (1956), and Barber (1989). Mapping in adjoining Coshocton County (Spahr, 1995) and Stark County (Williams, 1991) proved useful as a guideline for evaluating vadose zone materials. 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 media data. Information on parent materials derived from the *Soil Survey of Tuscarawas County* (Waters and Roth, 1986), also proved useful in evaluating vadose zone materials. Water well log records on file at the ODNR, Division of Water, were the primary source of information on vadose zone media for the county.

Vadose zone media was given ratings of (9) and (8) for sand and gravel and ratings of (5), (6), (7), and (8) for sand and gravel interbedded with silt and clay layers for buried valley and tributaries containing coarser alluvium. 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 containing predominantly finer-grained alluvial and lacustrine deposits.

A vadose zone media rating of (6) was selected for the Massillon Sandstone-Pottsville Group bedrock adjacent to Stark County. A vadose zone media rating of (5) was selected for bedrock comprised of interbedded sandstones and shales of the Mississippian and Pennsylvanian Pottsville Group. Vadose zone media were assigned ratings of (4) for the interbedded sandstone, shales, limestones, and coals of the Pennsylvanian Allegheny rocks. A vadose zone rating of (3) was utilized for the interbedded, fine-grained bedrock of the Conemaugh Group in ridge tops and higher slopes. Overall, vadose zone ratings were higher along slopes and valleys than in adjacent ridge tops. It was determined that rocks along valley bottoms may contain more fracturing, which is reflected by slightly higher yields in these areas.

Hydraulic Conductivity

Published data for hydraulic conductivity for Tuscarawas County was found lacking. Information from Cummins and Sanderson (1947), Kaser (1960), Barber (1989), and the ODNR, Division of Water, Glacial State Aquifer Map and Bedrock State Aquifer Map proved valuable. Water well log records on file at the ODNR, Division of Water, were the primary sources of information. Hydraulic conductivity values utilized in adjoining Coshocton County (Spahr, 1995) and Stark County (Williams, 1991) 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 greater than 2,000 gallons per day per square foot (gpd/ft^2) (10) or 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 Tuscarawas River south of Dover, Sugar Creek, and Sandy Creek. For sand and gravel deposits along the margins of the buried valley and in tributaries with an aquifer media rating of (7), hydraulic conductivities of 700-1000 gpd/ft^2 (6) and 300-700 gpd/ft^2 (4) were chosen. For sand and gravel deposits with an aquifer rating of (6), hydraulic conductivity values ranged from 300-700 gpd/ft^2 (4). Sand and gravel deposits with an aquifer rating of (5) have been assigned hydraulic conductivity ratings of 300-700 gpd/ft^2 (4) or 100-300 gpd/ft^2 (2). In these deposits, thin sand and gravel lenses are interbedded with thicker sequences of finer-grained materials.

Bedrock aquifers with an aquifer rating of (6) have been assigned a hydraulic conductivity rating of 100-300 gpd/ft^2 (2). Bedrock aquifers with an aquifer rating of (5) and (4) were given hydraulic conductivity ratings of 100-300 gpd/ft^2 (2) or 1-100 gpd/ft^2 (1). The higher conductivity values were assigned to areas along slopes or valleys; these areas are typically thought to be more heavily fractured than the adjacent ridge tops. All of the bedrock aquifers with an aquifer rating of (3) were given a hydraulic conductivity rating of 1-100 gpd/ft^2 (1) due to the low permeability of these rocks.

APPENDIX B

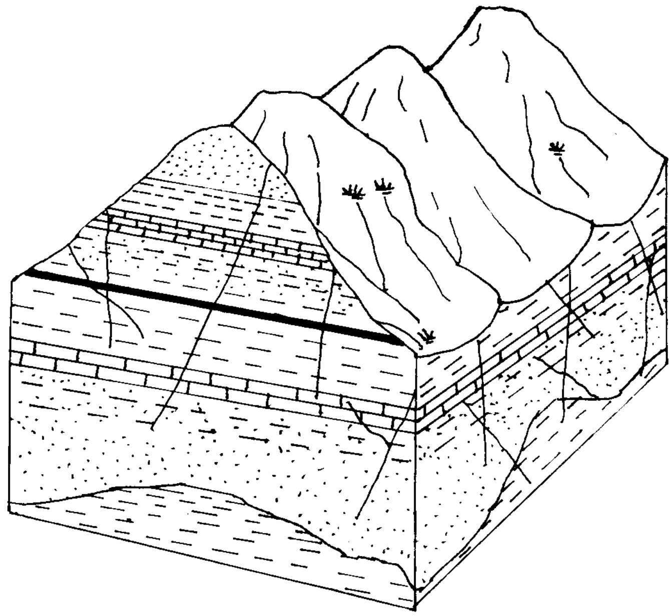
DESCRIPTION OF HYDROGEOLOGIC SETTINGS AND CHARTS

Ground water pollution potential mapping in Tuscarawas County resulted in the identification of 7 hydrogeologic settings within the Glaciated and Non-Glaciated Central Region. The list of these settings, the range of pollution potential index calculations, and the number of index calculations for each setting are provided in Table 13. Computed pollution potential indexes for Tuscarawas County range from 53 to 202.

Table 13. Hydrogeologic settings mapped in Tuscarawas County, Ohio

Hydrogeologic Settings	Range of GWPP Indexes	Number of Index Calculations
6Da - Alternating sandstone, limestone, shale-thin regolith	53-116	164
6Db-Alternating sandstone, limestone, shale-thick regolith	90-118	6
6Fb - River alluvium without overbank deposits	102-125	14
7Bb-Outwash over bedded sedimentary rocks	109-140	9
7D - Buried valley	119-202	69
7Fa - Glacial lakes and slack water terraces	102-138	21
7G-Thin glacial till over bedded sedimentary rocks	92-94	2

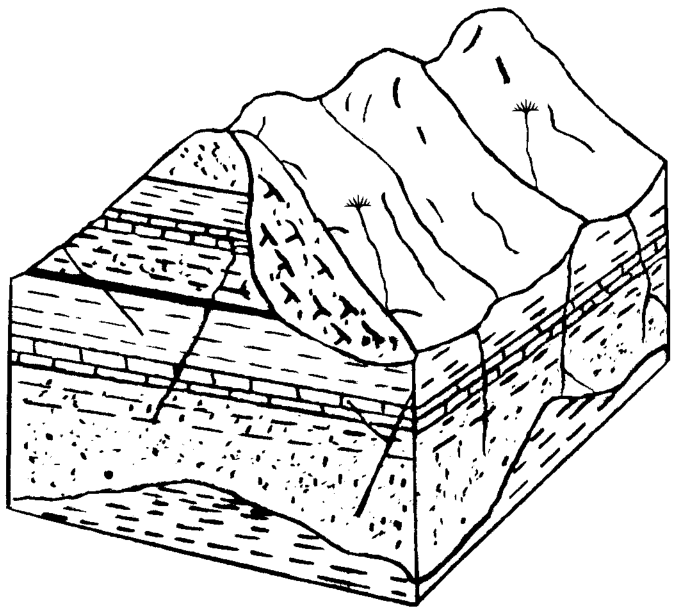
The following information provides a description of each hydrogeologic setting identified in the county, a block diagram illustrating the characteristics of the setting, and a listing of the charts for each unique combination of pollution potential indexes calculated for each setting. The charts provide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



<u>6Da Alternating Sandstone, Limestone, Shale – Thin Regolith</u>

This hydrogeologic setting is widespread, encompassing the upland areas in Tuscarawas 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 Mississippian and Pennsylvanian 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. Variable supplies of ground water are obtained from intersecting bedding planes or vertical fractures. Ground water yields average 25-100 gpm for the Pottsville Group - Massillon Sandstone, 10 to 25 gpm for the Mississippian System and Pottsville Group, 5 to 10 gpm for the Allegheny Group and less than 5 gpm for the Conemaugh Group. Recharge is limited due to the steep slopes, deep aquifers, and layers of impermeable bedrock.

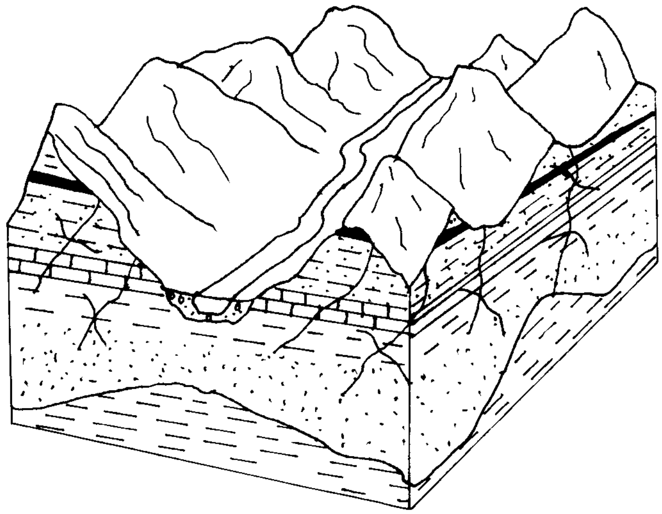
GWPP index values for the hydrogeologic setting of Alternating Sandstone, Limestone, Shale – Thin Regolith range from 53 to 116, with the total number of GWPP index calculations equaling 164.



<u>6Db Alternating Sandstone, Limestone, Shale – Thick Regolith</u>

This hydrogeologic setting is less common than the similar, typically adjacent 6Da Alternating Sandstone, Limestone, Shale – Thin Regolith. This setting is identical to the 6Da setting except that the surficial bedrock has weathered into thicker soils. This setting is usually found in the northern portion of the county. Along the toes of slopes, these settings commonly contain some colluvium. Soils are variable due to the differing bedrock lithologies. This setting is typically transitional between the ridge tops and higher slopes of the 6Da setting and stream valleys of the 6Fb Alluvium without Overbank Deposits and 7Fa Glacial Lakes and Slack Water Terraces. Depth to water tends to be moderate to deep. Recharge is moderate to low depending upon the depth to water, permeability of the soils, and amount of slope. Yields are similar to those of the 6Da setting.

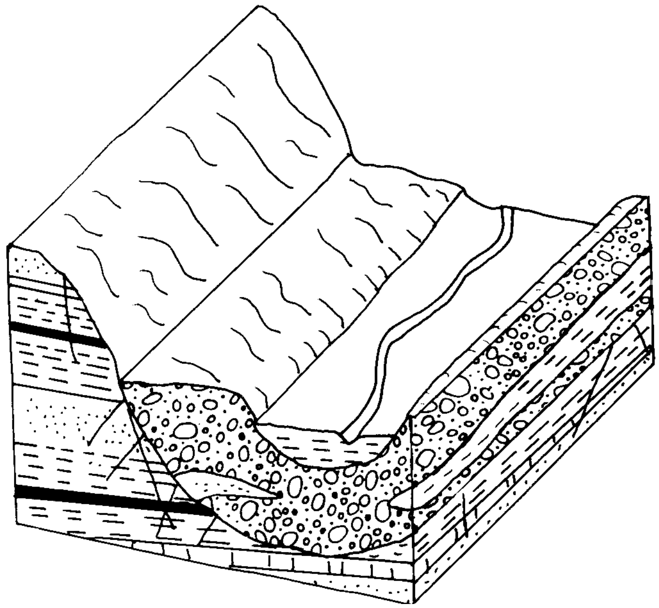
GWPP index values for the hydrogeologic setting of Alternating Sandstone, Limestone, Shale – Thick Regolith range from 90 to 118, with the total number of GWPP index calculations equaling 6.



6Fb River Alluvium without Overbank Deposits

This hydrogeologic setting is limited to small tributary valleys in the uplands of Tuscarawas 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 or loams. 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 Mississippian and Pennsylvanian System. In most areas, the alluvium is in direct connection with the underlying bedrock aquifers. Ground water yields range from 5 to 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.

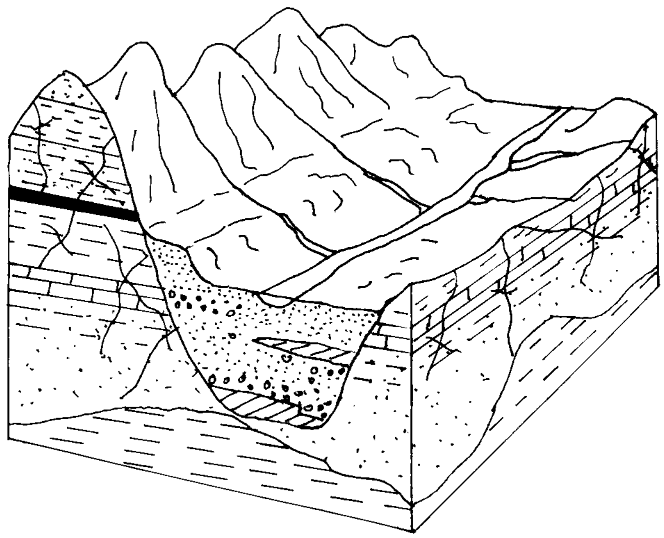
GWPP index values for the hydrogeologic setting of River Alluvium without Overbank Deposits range from 102 to 125, with the total number of GWPP index calculations equaling 14.



<u>7Bb Outwash over Bedded Sedimentary Rocks</u>

This hydrogeologic setting consists of relatively small, high-level outwash terraces deposited on top of bedrock benches. The total thickness of drift is not adequate enough 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 typically shallow to moderate and is usually less than 50 feet. Recharge is moderately high due to the relatively permeable soils and vadose, moderate to shallow depth to water, and relatively flat to rolling topography.

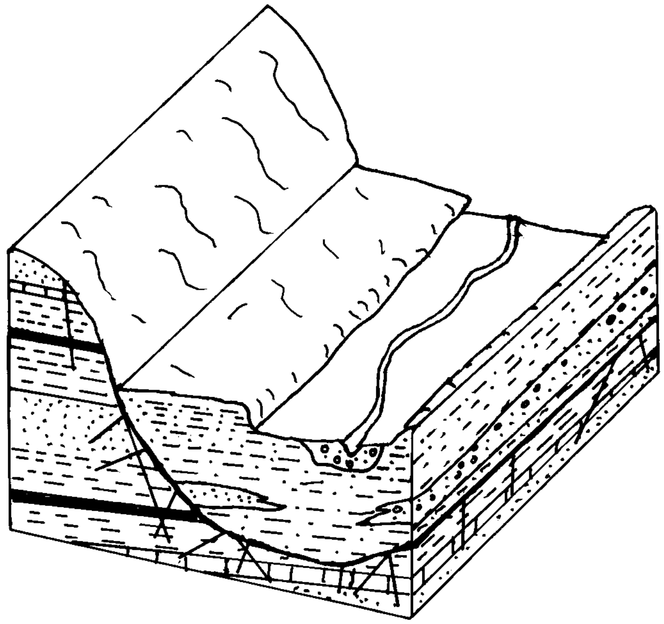
GWPP index values for the hydrogeologic setting of Outwash over Bedded Sedimentary Rocks range from 109 to 140, with the total number of GWPP index calculations equaling 9.



7D Buried Valley

This hydrogeologic setting is widespread throughout Tuscarawas County. All of the major trunk streams and many modern tributaries overlie buried valley deposits. The setting is easy to distinguish from the surrounding uplands; it is characterized by broad, flat-lying floodplains and gently sloping terraces. Depth to water is typically less than 30 feet, and is less than 15 feet when immediately adjacent to the primary trunk streams such as the Tuscarawas River, Sandy Creek, Sugar Creek, etc. Aquifers are composed of variable thicknesses of sand and gravel interbedded with finer-grained alluvium 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 the Tuscarawas River, Sandy Creek, and Sugar Creek. Along the margins of these valleys and tributaries, the outwash tends to be interbedded with finer-grained materials and yields range from 25 to 100 gpm. Some valleys, including Conotton Creek and Stillwater Creek, 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.

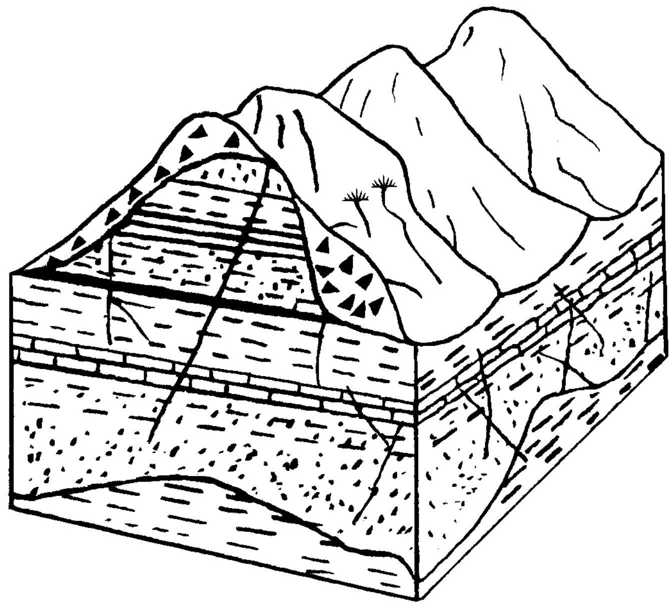
GWPP index values for the hydrogeologic setting of Buried Valley range from 119 to 202, with the total number of GWPP index calculations equaling 69.



<u>7Fa Glacial Lakes and Slackwater Terraces</u>

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. The valleys are typically broader and contain thicker, fine-grained, alluvial or lacustrine deposits than the somewhat similar 6Fb River Alluvium without 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. 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 102 to 138, with the total number of GWPP index calculations equaling 21.



<u>7G Thin Glacial Till Over Bedded Sedimentary Rock</u>

Moderate, rolling topography and deposits of thin, patchy glacial till overlying alternating layers of fractured sedimentary rock characterize this hydrogeologic setting. The till is less than 25 feet thick and consists of varying amounts of unsorted clay, silt, and sand with minor pebbles and cobbles. Ground water is obtained from the underlying, fractured Pennsylvanian bedrock. Depth to water is commonly fairly deep. Soils are silt loams or clay loams. Recharge is low due to depth to water and relatively impermeable nature of these soils.

GWPP index values for the hydrogeologic setting of Thin Glacial Till Over Bedded Sedimentary Rock range from 92 to 94, 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
6Da01	75-100	2-4	interbedded ss/sh/ls/coal	Sandy Loam	6-12	interbedded ss/sh/ls/coal	1-100	82
6Da02	75-100	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	6-12	interbedded ss/sh/ls/coal	1-100	84
6Da03	75-100	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	12-18	interbedded ss/sh/ls/coal	1-100	82
6Da04	75-100	4-7	interbedded ss/sh/ls/coal	Thin/Absent Gravel	12-18	interbedded ss/sh/ls/coal	100-300	111
6Da05	50-75	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	12-18	interbedded ss/sh/ls/coal	100-300	90
6Da06	50-75	2-4	interbedded ss/sh/ls/coal	Sandy Loam	12-18	interbedded ss/sh/ls/coal	1-100	85
6Da07	100+	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	12-18	interbedded ss/sh/ls/coal	100-300	80
6Da08	100+	2-4	interbedded ss/sh/ls/coal	Silty Loam	6-12	interbedded ss/sh/ls/coal	100-300	76
6Da09	50-75	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	6-12	interbedded ss/sh/ls/coal	100-300	92
6Da10	100+	2-4	interbedded ss/sh/ls/coal	Silty Loam	12-18	interbedded ss/sh/ls/coal	100-300	74
6Da11	30-50	4-7	interbedded ss/sh/ls/coal	Silty Loam	12-18	interbedded ss/sh/ls/coal	100-300	106
6Da12	100+	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	12-18	interbedded ss/sh/ls/coal	1-100	72
6Da13	100+	2-4	interbedded ss/sh/ls/coal	Silty Loam	2-6	interbedded ss/sh/ls/coal	1-100	72
6Da14	100+	2-4	interbedded ss/sh/ls/coal	Sandy Loam	18+	interbedded ss/sh/ls/coal	1-100	65
6Da15	100+	2-4	interbedded ss/sh/ls/coal	Silty Loam	12-18	interbedded ss/sh/ls/coal	1-100	55
6Da16	50-75	4-7	interbedded ss/sh/ls/coal	Thin/Absent Gravel	12-18	interbedded ss/sh/ls/coal	100-300	116
6Da17	50-75	4-7	interbedded ss/sh/ls/coal	Thin/Absent Gravel	18+	interbedded ss/sh/ls/coal	100-300	114
6Da18	50-75	2-4	interbedded ss/sh/ls/coal	Silty Loam	18+	interbedded ss/sh/ls/coal	1-100	71
6Da19	100+	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	6-12	interbedded ss/sh/ls/coal	1-100	71
6Da20	50-75	2-4	interbedded ss/sh/ls/coal	Silty Loam	18+	interbedded ss/sh/ls/coal	1-100	74
6Da21	100+	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	12-18	interbedded ss/sh/ls/coal	1-100	61
6Da22	50-75	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	12-18	interbedded ss/sh/ls/coal	1-100	87
6Da23	75-100	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	12-18	interbedded ss/sh/ls/coal	100-300	85
6Da24	75-100	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	6-12	interbedded ss/sh/ls/coal	100-300	87
6Da25	75-100	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	2-6	interbedded ss/sh/ls/coal	100-300	91

Setting	Depth To Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% Slope)	Vadose Zone Media	Hydraulic Conductivity	Rating
6Da26	30-50	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	silt/clay	1-100	102
6Da27	50-75	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	6-12	interbedded ss/sh/ls/coal	1-100	84
6Da28	30-50	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	12-18	interbedded ss/sh/ls/coal	1-100	97
6Da29	50-75	2-4	interbedded ss/sh/ls/coal	Silty Loam	0-2	interbedded ss/sh/ls/coal	100-300	91
6Da30	50-75	2-4	interbedded ss/sh/ls/coal	Silty Loam	12-18	interbedded ss/sh/ls/coal	100-300	84
6Da31	50-75	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	18+	interbedded ss/sh/ls/coal	1-100	85
6Da32	50-75	2-4	interbedded ss/sh/ls/coal	Sandy Loam	18+	interbedded ss/sh/ls/coal	1-100	83
6Da33	30-50	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	6-12	interbedded ss/sh/ls/coal	100-300	102
6Da34	100+	2-4	interbedded ss/sh/ls/coal	Silty Loam	18+	interbedded ss/sh/ls/coal	1-100	61
6Da35	30-50	2-4	interbedded ss/sh/ls/coal	Silty Loam	6-12	interbedded ss/sh/ls/coal	100-300	96
6Da36	50-75	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	6-12	interbedded ss/sh/ls/coal	1-100	89
6Da37	30-50	2-4	interbedded ss/sh/ls/coal	Sandy Loam	12-18	interbedded ss/sh/ls/coal	1-100	95
6Da38	30-50	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	6-12	interbedded ss/sh/ls/coal	1-100	99
6Da39	30-50	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	2-6	interbedded ss/sh/ls/coal	100-300	106
6Da40	30-50	2-4	interbedded ss/sh/ls/coal	Silty Loam	12-18	interbedded ss/sh/ls/coal	1-100	86
6Da41	50-75	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	12-18	interbedded ss/sh/ls/coal	1-100	79
6Da42	50-75	2-4	interbedded ss/sh/ls/coal	Sandy Loam	18+	interbedded ss/sh/ls/coal	1-100	75
6Da43	30-50	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	18+	interbedded ss/sh/ls/coal	1-100	95
6Da44	30-50	2-4	interbedded ss/sh/ls/coal	Sandy Loam	6-12	interbedded ss/sh/ls/coal	100-300	100
6Da45	30-50	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	18+	interbedded ss/sh/ls/coal	1-100	90
6Da46	30-50	2-4	interbedded ss/sh/ls/coal	Sandy Loam	12-18	interbedded ss/sh/ls/coal	1-100	90
6Da48	100+	2-4	interbedded ss/sh/ls/coal	Sandy Loam	18+	interbedded ss/sh/ls/coal	1-100	73
6Da49	50-75	2-4	interbedded ss/sh/ls/coal	Silty Loam	12-18	interbedded ss/sh/ls/coal	1-100	81
6Da50	100+	2-4	interbedded ss/sh/ls/coal	Sandy Loam	12-18	interbedded ss/sh/ls/coal	1-100	75
6Da51	50-75	2-4	interbedded ss/sh/ls/coal	Silty Loam	18+	interbedded ss/sh/ls/coal	1-100	79
6Da52	50-75	2-4	interbedded ss/sh/ls/coal	Silty Loam	18+	interbedded ss/sh/ls/coal	100-300	82
6Da53	30-50	2-4	interbedded ss/sh/ls/coal	Sandy Loam	18+	interbedded ss/sh/ls/coal	1-100	93

Setting	Depth To Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% Slope)	Vadose Zone Media	Hydraulic Conductivity	Rating
6Da54	30-50	2-4	interbedded ss/sh/ls/coal	Sandy Loam	6-12	interbedded ss/sh/ls/coal	1-100	97
6Da55	50-75	2-4	interbedded ss/sh/ls/coal	Sandy Loam	6-12	interbedded ss/sh/ls/coal	1-100	87
6Da56	100+	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	12-18	interbedded ss/sh/ls/coal	1-100	77
6Da57	30-50	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	18+	interbedded ss/sh/ls/coal	100-300	98
6Da58	50-75	2-4	interbedded ss/sh/ls/coal	Sandy Loam	18+	interbedded ss/sh/ls/coal	100-300	86
6Da59	50-75	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	18+	interbedded ss/sh/ls/coal	1-100	91
6Da60	50-75	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	18+	interbedded ss/sh/ls/coal	100-300	94
6Da61	50-75	0-2	interbedded ss/sh/ls/coal	Thin/Absent Gravel	18+	interbedded ss/sh/ls/coal	1-100	83
6Da62	100+	2-4	interbedded ss/sh/ls/coal	Sandy Loam	2-6	interbedded ss/sh/ls/coal	1-100	73
6Da63	50-75	0-2	interbedded ss/sh/ls/coal	Thin/Absent Gravel	18+	interbedded ss/sh/ls/coal	1-100	78
6Da64	50-75	2-4	interbedded ss/sh/ls/coal	Sandy Loam	18+	interbedded ss/sh/ls/coal	1-100	78
6Da65	50-75	2-4	interbedded ss/sh/ls/coal	Silty Loam	12-18	interbedded ss/sh/ls/coal	1-100	73
6Da66	50-75	2-4	interbedded ss/sh/ls/coal	Silty Loam	12-18	interbedded ss/sh/ls/coal	1-100	65
6Da67	30-50	2-4	interbedded ss/sh/ls/coal	Silty Loam	12-18	interbedded ss/sh/ls/coal	1-100	83
6Da68	50-75	2-4	interbedded ss/sh/ls/coal	Silty Loam	18+	interbedded ss/sh/ls/coal	1-100	63
6Da69	75-100	2-4	interbedded ss/sh/ls/coal	Silty Loam	18+	interbedded ss/sh/ls/coal	1-100	58
6Da70	75-100	0-2	interbedded ss/sh/ls/coal	Thin/Absent Gravel	18+	interbedded ss/sh/ls/coal	1-100	70
6Da71	75-100	0-2	interbedded ss/sh/ls/coal	Thin/Absent Gravel	18+	interbedded ss/sh/ls/coal	1-100	73
6Da72	50-75	0-2	interbedded ss/sh/ls/coal	Thin/Absent Gravel	18+	interbedded ss/sh/ls/coal	1-100	75
6Da73	50-75	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	18+	interbedded ss/sh/ls/coal	1-100	80
6Da74	50-75	2-4	interbedded ss/sh/ls/coal	Silty Loam	6-12	interbedded ss/sh/ls/coal	1-100	67
6Da75	50-75	2-4	interbedded ss/sh/ls/coal	Sandy Loam	18+	interbedded ss/sh/ls/coal	1-100	72
6Da77	30-50	2-4	interbedded ss/sh/ls/coal	Silty Loam	18+	interbedded ss/sh/ls/coal	1-100	78
6Da78	30-50	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	18+	interbedded ss/sh/ls/coal	1-100	84
6Da79	30-50	2-4	interbedded ss/sh/ls/coal	Sandy Loam	18+	interbedded ss/sh/ls/coal	1-100	85
6Da80	50-75	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	18+	interbedded ss/sh/ls/coal	1-100	75
6Da81	75-100	2-4	interbedded ss/sh/ls/coal	Silty Loam	18+	interbedded ss/sh/ls/coal	1-100	58

Setting	Depth To Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% Slope)	Vadose Zone Media	Hydraulic Conductivity	Rating
6Da82	75-100	0-2	interbedded ss/sh/ls/coal	Thin/Absent Gravel	18+	interbedded ss/sh/ls/coal	1-100	62
6Da83	30-50	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	18+	interbedded ss/sh/ls/coal	1-100	85
6Da84	30-50	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	18+	interbedded ss/sh/ls/coal	1-100	87
6Da85	15-30	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	18+	interbedded ss/sh/ls/coal	1-100	98
6Da86	15-30	2-4	interbedded ss/sh/ls/coal	Silty Loam	18+	interbedded ss/sh/ls/coal	1-100	91
6Da87	50-75	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	6-12	interbedded ss/sh/ls/coal	1-100	73
6Da88	100+	2-4	interbedded ss/sh/ls/coal	Silty Loam	18+	interbedded ss/sh/ls/coal	1-100	53
6Da89	100+	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	18+	interbedded ss/sh/ls/coal	1-100	65
6Da90	30-50	2-4	interbedded ss/sh/ls/coal	Silty Loam	2-6	interbedded ss/sh/ls/coal	100-300	100
6Da91	100+	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	6-12	interbedded ss/sh/ls/coal	1-100	63
6Da92	100+	2-4	interbedded ss/sh/ls/coal	Sandy Loam	18+	interbedded ss/sh/ls/coal	1-100	62
6Da93	75-100	2-4	interbedded ss/sh/ls/coal	Sandy Loam	18+	interbedded ss/sh/ls/coal	1-100	70
6Da94	75-100	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	12-18	interbedded ss/sh/ls/coal	100-300	77
6Da95	100+	2-4	interbedded ss/sh/ls/coal	Silty Loam	12-18	interbedded ss/sh/ls/coal	100-300	66
6Da96	100+	2-4	interbedded ss/sh/ls/coal	Silty Loam	6-12	interbedded ss/sh/ls/coal	100-300	68
6Da97	100+	2-4	interbedded ss/sh/ls/coal	Silty Loam	12-18	interbedded ss/sh/ls/coal	1-100	63
6Da98	30-50	2-4	interbedded ss/sh/ls/coal	Clay Loam	12-18	interbedded ss/sh/ls/coal	100-300	87
6Da99	50-75	2-4	interbedded ss/sh/ls/coal	Loam	18+	interbedded ss/sh/ls/coal	1-100	73
6Da100	50-75	2-4	interbedded ss/sh/ls/coal	Clay Loam	18+	interbedded ss/sh/ls/coal	1-100	69
6Da101	30-50	2-4	interbedded ss/sh/ls/coal	Clay Loam	18+	interbedded ss/sh/ls/coal	100-300	85
6Da102	50-75	2-4	interbedded ss/sh/ls/coal	Clay Loam	12-18	interbedded ss/sh/ls/coal	1-100	71
6Da103	100+	2-4	interbedded ss/sh/ls/coal	Sandy Loam	12-18	interbedded ss/sh/ls/coal	1-100	67
6Da104	50-75	2-4	interbedded ss/sh/ls/coal	Sandy Loam	6-12	interbedded ss/sh/ls/coal	1-100	79
6Da105	50-75	2-4	interbedded ss/sh/ls/coal	Sandy Loam	12-18	interbedded ss/sh/ls/coal	1-100	77
6Da106	100+	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	18+	interbedded ss/sh/ls/coal	1-100	67
6Da107	30-50	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	12-18	interbedded ss/sh/ls/coal	100-300	92
6Da108	100+	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	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
6Da109	30-50	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	18+	interbedded ss/sh/ls/coal	100-300	90
6Da110	30-50	2-4	interbedded ss/sh/ls/coal	Sandy Loam	18+	interbedded ss/sh/ls/coal	100-300	88
6Da111	30-50	2-4	interbedded ss/sh/ls/coal	Sandy Loam	12-18	interbedded ss/sh/ls/coal	100-300	90
6Da112	50-75	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	18+	interbedded ss/sh/ls/coal	1-100	77
6Da113	75-100	2-4	interbedded ss/sh/ls/coal	Sandy Loam	12-18	interbedded ss/sh/ls/coal	100-300	75
6Da114	75-100	2-4	interbedded ss/sh/ls/coal	Sandy Loam	12-18	interbedded ss/sh/ls/coal	1-100	72
6Da115	30-50	2-4	interbedded ss/sh/ls/coal	Loam	18+	interbedded ss/sh/ls/coal	100-300	89
6Da116	75-100	2-4	interbedded ss/sh/ls/coal	Silty Loam	18+	interbedded ss/sh/ls/coal	1-100	66
6Da117	75-100	2-4	interbedded ss/sh/ls/coal	Silty Loam	12-18	interbedded ss/sh/ls/coal	100-300	71
6Da118	75-100	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	18+	interbedded ss/sh/ls/coal	1-100	72
6Da119	100+	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	18+	interbedded ss/sh/ls/coal	1-100	73
6Da120	100+	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	12-18	interbedded ss/sh/ls/coal	1-100	75
6Da121	100+	2-4	interbedded ss/sh/ls/coal	Sandy Loam	12-18	interbedded ss/sh/ls/coal	1-100	67
6Da122	30-50	2-4	interbedded ss/sh/ls/coal	Silty Loam	2-6	interbedded ss/sh/ls/coal	100-300	92
6Da123	30-50	2-4	interbedded ss/sh/ls/coal	Silty Loam	12-18	interbedded ss/sh/ls/coal	100-300	89
6Da124	30-50	2-4	interbedded ss/sh/ls/coal	Silty Loam	18+	interbedded ss/sh/ls/coal	100-300	87
6Da125	75-100	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	18+	interbedded ss/sh/ls/coal	1-100	78
6Da126	75-100	2-4	interbedded ss/sh/ls/coal	Sandy Loam	18+	interbedded ss/sh/ls/coal	1-100	67
6Da127	50-75	0-2	interbedded ss/sh/ls/coal	Thin/Absent Gravel	18+	interbedded ss/sh/ls/coal	1-100	72
6Da128	50-75	2-4	interbedded ss/sh/ls/coal	Silty Loam	6-12	interbedded ss/sh/ls/coal	1-100	75
6Da129	50-75	0-2	interbedded ss/sh/ls/coal	Thin/Absent Gravel	12-18	interbedded ss/sh/ls/coal	1-100	69
6Da130	50-75	0-2	interbedded ss/sh/ls/coal	Thin/Absent Gravel	6-12	interbedded ss/sh/ls/coal	1-100	76
6Da131	50-75	2-4	interbedded ss/sh/ls/coal	Sandy Loam	6-12	interbedded ss/sh/ls/coal	1-100	76
6Da132	50-75	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	18+	interbedded ss/sh/ls/coal	1-100	69
6Da133	50-75	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	6-12	interbedded ss/sh/ls/coal	1-100	81
6Da134	100+	2-4	interbedded ss/sh/ls/coal	Silty Loam	6-12	interbedded ss/sh/ls/coal	1-100	65
6Da135	50-75	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	12-18	interbedded ss/sh/ls/coal	1-100	74

Setting	Depth To Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% Slope)	Vadose Zone Media	Hydraulic Conductivity	Rating
6Da136	50-75	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	18+	interbedded ss/sh/ls/coal	1-100	83
6Da137	100+	2-4	interbedded ss/sh/ls/coal	Sandy Loam	6-12	interbedded ss/sh/ls/coal	1-100	69
6Da138	50-75	2-4	interbedded ss/sh/ls/coal	Silty Loam	2-6	interbedded ss/sh/ls/coal	1-100	79
6Da139	30-50	2-4	interbedded ss/sh/ls/coal	Silty Loam	18+	interbedded ss/sh/ls/coal	100-300	92
6Da140	50-75	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	18+	interbedded ss/sh/ls/coal	100-300	88
6Da141	50-75	0-2	interbedded ss/sh/ls/coal	Thin/Absent Gravel	18+	interbedded ss/sh/ls/coal	1-100	67
6Da143	50-75	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	18+	interbedded ss/sh/ls/coal	1-100	78
6Da144	50-75	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	12-18	interbedded ss/sh/ls/coal	1-100	77
6Da145	50-75	0-2	interbedded ss/sh/ls/coal	Thin/Absent Gravel	6-12	interbedded ss/sh/ls/coal	1-100	79
6Da146	50-75	2-4	interbedded ss/sh/ls/coal	Sandy Loam	18+	interbedded ss/sh/ls/coal	1-100	67
6Da147	30-50	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	6-12	interbedded ss/sh/ls/coal	1-100	97
6Da148	100+	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	6-12	interbedded ss/sh/ls/coal	1-100	69
6Da149	30-50	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	18+	interbedded ss/sh/ls/coal	1-100	93
6Da150	50-75	2-4	interbedded ss/sh/ls/coal	Clay Loam	18+	interbedded ss/sh/ls/coal	1-100	61
6Da151	50-75	2-4	interbedded ss/sh/ls/coal	Clay Loam	6-12	interbedded ss/sh/ls/coal	1-100	65
6Da152	50-75	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	12-18	interbedded ss/sh/ls/coal	1-100	71
6Da153	50-75	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	6-12	interbedded ss/sh/ls/coal	1-100	79
6Da154	100+	2-4	interbedded ss/sh/ls/coal	Silty Loam	6-12	interbedded ss/sh/ls/coal	1-100	57
6Da155	100+	0-2	interbedded ss/sh/ls/coal	Thin/Absent Gravel	18+	interbedded ss/sh/ls/coal	1-100	57
6Da156	100+	2-4	interbedded ss/sh/ls/coal	Sandy Loam	18+	interbedded ss/sh/ls/coal	1-100	57
6Da157	100+	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	18+	interbedded ss/sh/ls/coal	1-100	59
6Da158	75-100	2-4	interbedded ss/sh/ls/coal	Sandy Loam	6-12	interbedded ss/sh/ls/coal	1-100	66
6Da159	30-50	2-4	interbedded ss/sh/ls/coal	Silty Loam	18+	interbedded ss/sh/ls/coal	1-100	73
6Da160	100+	0-2	interbedded ss/sh/ls/coal	Thin/Absent Gravel	18+	interbedded ss/sh/ls/coal	1-100	62
6Da161	30-50	4-7	interbedded ss/sh/ls/coal	Sandy Loam	2-6	interbedded ss/sh/ls/coal	100-300	116
6Da162	30-50	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	interbedded ss/sh/ls/coal	100-300	113
6Da163	50-75	2-4	interbedded ss/sh/ls/coal	Thin/Absent Gravel	18+	interbedded ss/sh/ls/coal	100-300	89

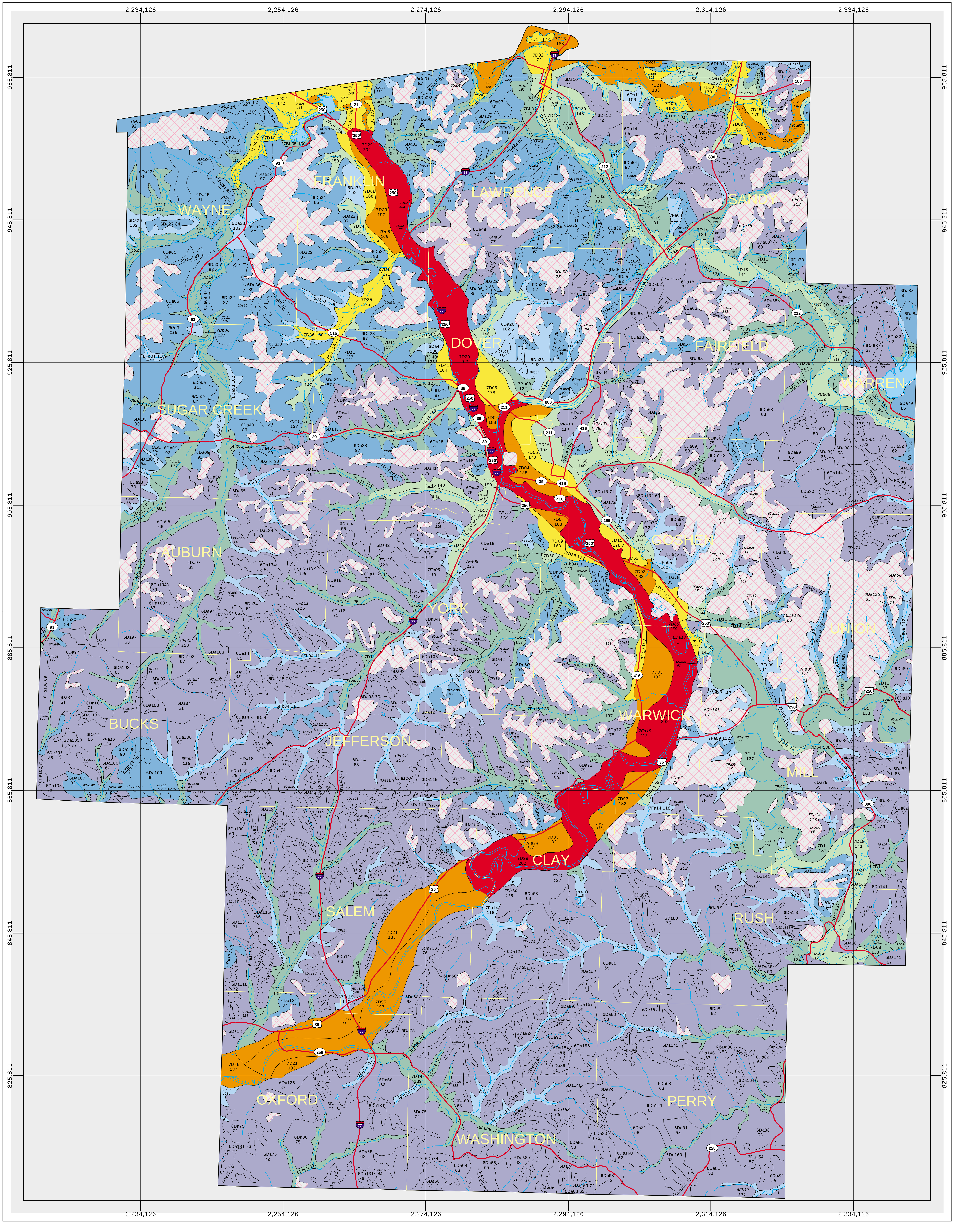
Setting	Depth To Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% Slope)	Vadose Zone Media	Hydraulic Conductivity	Rating
6Da164	100+	2-4	interbedded ss/sh/ls/coal	Sandy Loam	18+	interbedded ss/sh/ls/coal	1-100	57
6Db01	50-75	2-4	interbedded ss/sh/ls/coal	Silty Loam	12-18	interbedded ss/sh/ls/coal	100-300	92
6Db02	50-75	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	12-18	interbedded ss/sh/ls/coal	100-300	98
6Db03	50-75	2-4	interbedded ss/sh/ls/coal	Silty Loam	18+	interbedded ss/sh/ls/coal	100-300	90
6Db04	30-50	4-7	interbedded ss/sh/ls/coal	Shrink/Swell Clay	2-6	interbedded ss/sh/ls/coal	100-300	118
6Db05	30-50	4-7	interbedded ss/sh/ls/coal	Loam	0-2	interbedded ss/sh/ls/coal	100-300	115
6Db06	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	6-12	interbedded ss/sh/ls/coal	100-300	118
6Fb01	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	silt/clay	100-300	118
6Fb02	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	sd+gvl w/sig.sl+cl	100-300	123
6Fb03	15-30	4-7	interbedded ss/sh/ls/coal	Loam	0-2	sd+gvl w/sig.sl+cl	100-300	125
6Fb04	30-50	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	sd+gvl w/sig.sl+cl	100-300	113
6Fb05	30-50	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	silt/clay	1-100	102
6Fb06	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	2-6	interbedded ss/sh/ls/coal	100-300	122
6Fb07	30-50	4-7	interbedded ss/sh/ls/coal	Silty Loam	6-12	sd+gvl w/sig.sl+cl	100-300	108
6Fb08	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	silt/clay	100-300	115
6Fb09	15-30	4-7	interbedded ss/sh/ls/coal	Loam	0-2	sd+gvl w/sig.sl+cl	100-300	122
6Fb10	30-50	4-7	interbedded ss/sh/ls/coal	Loam	0-2	sd+gvl w/sig.sl+cl	100-300	112
6Fb11	30-50	4-7	interbedded ss/sh/ls/coal	Loam	0-2	sd+gvl w/sig.sl+cl	100-300	115
6Fb12	30-50	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	silt/clay	100-300	105
6Fb13	30-50	4-7	interbedded ss/sh/ls/coal	Loam	0-2	silt/clay	1-100	104
6Fb14	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	silt/clay	1-100	112
7Bb01	30-50	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	sand and gravel	100-300	136
7Bb02	30-50	4-7	interbedded ss/sh/ls/coal	Sandy Loam	0-2	sd+gvl w/sig.sl+cl	100-300	122
7Bb03	5-15	4-7	interbedded ss/sh/ls/coal	Loam	0-2	interbedded ss/sh/ls/coal	100-300	140
7Bb04	15-30	4-7	interbedded ss/sh/ls/coal	Sandy Loam	0-2	sd+gvl w/sig.sl+cl	1-100	129

Setting	Depth To Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% Slope)	Vadose Zone Media	Hydraulic Conductivity	Rating
7Bb05	15-30	4-7	interbedded ss/sh/ls/coal	Loam	0-2	sd+gvl w/sig.sl+cl	100-300	130
7Bb06	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	2-6	sd+gvl w/sig.sl+cl	100-300	127
7Bb07	30-50	4-7	interbedded ss/sh/ls/coal	Sandy Loam	2-6	sd+gvl w/sig.sl+cl	100-300	121
7Bb08	30-50	4-7	interbedded ss/sh/ls/coal	Sandy Loam	0-2	sd+gvl w/sig.sl+cl	100-300	122
7Bb09	30-50	2-4	interbedded ss/sh/ls/coal	Sandy Loam	2-6	sd+gvl w/sig.sl+cl	100-300	109
7D01	30-50	7-10	sand + gravel	Sand	2-6	sd+gvl w/sig.sl+cl	1000-2000	167
7D02	30-50	7-10	sand + gravel	Sandy Loam	0-2	sand and gravel	1000-2000	172
7D03	15-30	7-10	sand + gravel	Sandy Loam	0-2	sand and gravel	1000-2000	182
7D04	15-30	7-10	sand + gravel	Sandy Loam	0-2	sand and gravel	2000+	188
7D05	30-50	7-10	sand + gravel	Sandy Loam	0-2	sand and gravel	2000+	178
7D06	30-50	7-10	sand + gravel	Sandy Loam	0-2	sand and gravel	700-1000	158
7D07	30-50	4-7	sand + gravel	Silty Loam	0-2	sand and gravel	1000-2000	160
7D08	15-30	7-10	sand + gravel	Sandy Loam	0-2	sand and gravel	700-1000	168
7D09	15-30	7-10	sand + gravel	Sandy Loam	0-2	sd+gvl w/sig.sl+cl	700-1000	163
7D10	15-30	7-10	sand + gravel	Loam	0-2	sd+gvl w/sig.sl+cl	700-1000	161
7D11	15-30	4-7	sand + gravel	Silty Loam	0-2	sd+gvl w/sig.sl+cl	300-700	137
7D12	5-15	7-10	sand + gravel	Loam	0-2	sand and gravel	300-700	172
7D13	15-30	7-10	sand + gravel	Sand	0-2	sand and gravel	1000-2000	188
7D14	15-30	4-7	sand + gravel	Loam	0-2	sd+gvl w/sig.sl+cl	300-700	139
7D15	30-50	7-10	sand + gravel	Sand	0-2	sand and gravel	1000-2000	178
7D16	30-50	7-10	sand + gravel	Sandy Loam	0-2	sd+gvl w/sig.sl+cl	700-1000	153
7D17	5-15	7-10	sand + gravel	Loam	0-2	sd+gvl w/sig.sl+cl	700-1000	171
7D18	15-30	4-7	sand + gravel	Sandy Loam	0-2	sd+gvl w/sig.sl+cl	300-700	141
7D19	30-50	4-7	sand + gravel	Sandy Loam	0-2	sd+gvl w/sig.sl+cl	300-700	131
7D20	30-50	4-7	sand + gravel	Sandy Loam	0-2	sd+gvl w/sig.sl+cl	700-1000	145
7D21	15-30	7-10	sand + gravel	Sandy Loam	0-2	sand and gravel	2000+	183

Setting	Depth To Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% Slope)	Vadose Zone Media	Hydraulic Conductivity	Rating
7D22	30-50	4-7	sand + gravel	Silty Loam	2-6	sd+gvl w/sig.sl+cl	300-700	126
7D23	30-50	7-10	sand + gravel	Sandy Loam	0-2	sand and gravel	2000+	173
7D24	15-30	7-10	sand + gravel	Sand	0-2	sand and gravel	300-700	170
7D25	15-30	7-10	sand + gravel	Silty Loam	0-2	sand and gravel	2000+	179
7D26	30-50	7-10	sand + gravel	Sandy Loam	0-2	sd+gvl w/sig.sl+cl	300-700	139
7D27	15-30	7-10	sand + gravel	Silty Loam	0-2	sd+gvl w/sig.sl+cl	300-700	145
7D28	15-30	7-10	sand + gravel	Sandy Loam	0-2	sd+gvl w/sig.sl+cl	300-700	149
7D29	5-15	10+	sand + gravel	Sandy Loam	0-2	sand and gravel	2000+	202
7D30	15-30	4-7	sand + gravel	Loam	0-2	sd+gvl w/sig.sl+cl	100-300	130
7D31	15-30	4-7	sand + gravel	Silty Loam	2-6	sd+gvl w/sig.sl+cl	100-300	127
7D32	15-30	4-7	sand + gravel	Silty Loam	0-2	sd+gvl w/sig.sl+cl	300-700	132
7D33	5-15	7-10	sand + gravel	Sandy Loam	0-2	sand and gravel	1000-2000	192
7D34	15-30	7-10	sand + gravel	Silty Loam	0-2	sd+gvl w/sig.sl+cl	700-1000	159
7D35	0-5	10+	sand + gravel	Loam	0-2	sd+gvl w/sig.sl+cl	700-1000	175
7D36	0-5	7-10	sand + gravel	Silty Loam	0-2	sd+gvl w/sig.sl+cl	300-700	160
7D37	5-15	7-10	sand + gravel	Silty Loam	0-2	sd+gvl w/sig.sl+cl	700-1000	164
7D38	5-15	4-7	sand + gravel	Silty Loam	0-2	sd+gvl w/sig.sl+cl	300-700	147
7D39	30-50	4-7	sand + gravel	Silty Loam	0-2	sd+gvl w/sig.sl+cl	300-700	127
7D40	15-30	4-7	sand + gravel	Loam	0-2	sd+gvl w/sig.sl+cl	100-300	125
7D41	5-15	7-10	sand + gravel	Sandy Loam	0-2	sd+gvl w/sig.sl+cl	300-700	164
7D42	30-50	4-7	sand + gravel	Sandy Loam	2-6	sd+gvl w/sig.sl+cl	300-700	133
7D43	15-30	4-7	sand + gravel	Loam	0-2	sd+gvl w/sig.sl+cl	300-700	142
7D44	15-30	4-7	sand + gravel	Silty Loam	0-2	sd+gvl w/sig.sl+cl	700-1000	146
7D45	15-30	4-7	sand + gravel	Silty Loam	0-2	sd+gvl w/sig.sl+cl	300-700	140
7D46	5-15	7-10	sand + gravel	Sandy Loam	0-2	sd+gvl w/sig.sl+cl	300-700	159
7D47	15-30	7-10	sand + gravel	Sandy Loam	0-2	sd+gvl w/sig.sl+cl	300-700	152
7D48	15-30	7-10	sand + gravel	Sandy Loam	0-2	sd+gvl w/sig.sl+cl	300-700	157

Setting	Depth To Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% Slope)	Vadose Zone Media	Hydraulic Conductivity	Rating
7D49	30-50	4-7	interbedded ss/sh/ls/coal	Shrink/Swell Clay	0-2	silt/clay	300-700	126
7D50	15-30	4-7	sand + gravel	Silty Loam	0-2	sand and gravel	300-700	140
7D51	30-50	4-7	sand + gravel	Loam	0-2	sd+gvl w/sig.sl+cl	300-700	124
7D52	15-30	4-7	sand + gravel	Silty Loam	0-2	sd+gvl w/sig.sl+cl	300-700	129
7D53	30-50	4-7	sand + gravel	Silty Loam	0-2	sd+gvl w/sig.sl+cl	300-700	119
7D54	15-30	4-7	sand + gravel	Shrink/Swell Clay	0-2	silt/clay	300-700	138
7D55	5-15	7-10	sand + gravel	Sandy Loam	0-2	sand and gravel	2000+	193
7D56	5-15	7-10	sand + gravel	Sandy Loam	0-2	sand and gravel	1000-2000	187
7D57	15-30	4-7	sand + gravel	Loam	0-2	sd+gvl w/sig.sl+cl	700-1000	148
7D58	15-30	4-7	sand + gravel	Loam	0-2	sd+gvl w/sig.sl+cl	300-700	126
7D59	5-15	7-10	sand + gravel	Sandy Loam	0-2	sd+gvl w/sig.sl+cl	700-1000	173
7D60	15-30	4-7	sand + gravel	Sandy Loam	0-2	sd+gvl w/sig.sl+cl	300-700	144
7D61	30-50	7-10	sand + gravel	Sand	0-2	sd+gvl w/sig.sl+cl	700-1000	159
7D62	30-50	7-10	sand + gravel	Sandy Loam	0-2	sd+gvl w/sig.sl+cl	1000-2000	167
7D64	15-30	7-10	sand + gravel	Sandy Loam	0-2	sd+gvl w/sig.sl+cl	1000-2000	177
7D65	15-30	4-7	sand + gravel	Sandy Loam	0-2	sd+gvl w/sig.sl+cl	700-1000	150
7D66	15-30	7-10	sand + gravel	Sandy Loam	0-2	sd+gvl w/sig.sl+cl	700-1000	158
7D67	15-30	4-7	sand + gravel	Silty Loam	0-2	silt/clay	300-700	124
7D68	15-30	4-7	sand + gravel	Sandy Loam	0-2	sd+gvl w/sig.sl+cl	300-700	133
7D69	15-30	4-7	sand + gravel	Shrink/Swell Clay	0-2	silt/clay	300-700	130
7Fa01	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	silt/clay	100-300	121
7Fa02	5-15	4-7	interbedded ss/sh/ls/coal	Loam	0-2	silt/clay	100-300	138
7Fa03	15-30	4-7	interbedded ss/sh/ls/coal	Loam	0-2	silt/clay	100-300	120
7Fa04	30-50	4-7	interbedded ss/sh/ls/coal	Silty Loam	2-6	silt/clay	100-300	112
7Fa05	30-50	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	silt/clay	100-300	113
7Fa06	15-30	4-7	sand + gravel	Loam	0-2	silt/clay	300-700	129
7Fa07	15-30	4-7	interbedded ss/sh/ls/coal	Loam	0-2	sd+gvl w/sig.sl+cl	1-100	119

Setting	Depth To Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% Slope)	Vadose Zone Media	Hydraulic Conductivity	Rating
7Fa08	30-50	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	sd+gvl w/sig.sl+cl	1-100	110
7Fa09	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	silt/clay	1-100	112
7Fa10	30-50	4-7	interbedded ss/sh/ls/coal	Shrink/Swell Clay	0-2	silt/clay	100-300	114
7Fa12	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	2-6	silt/clay	100-300	122
7Fa13	15-30	4-7	interbedded ss/sh/ls/coal	Loam	2-6	silt/clay	100-300	124
7Fa14	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	silt/clay	100-300	118
7Fa15	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	2-6	silt/clay	100-300	117
7Fa16	15-30	4-7	interbedded ss/sh/ls/coal	Loam	0-2	silt/clay	100-300	125
7Fa17	30-50	4-7	interbedded ss/sh/ls/coal	Loam	0-2	sd+gvl w/sig.sl+cl	100-300	115
7Fa18	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	silt/clay	100-300	123
7Fa19	30-50	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	silt/clay	1-100	102
7Fa21	15-30	4-7	interbedded ss/sh/ls/coal	Shrink/Swell Clay	2-6	silt/clay	100-300	123
7G01	50-75	2-4	interbedded ss/sh/ls/coal	Clay Loam	6-12	interbedded ss/sh/ls/coal	100-300	92
7G02	50-75	2-4	interbedded ss/sh/ls/coal	Silty Loam	6-12	interbedded ss/sh/ls/coal	100-300	94



Ground Water Pollution Potential of Tuscarawas County

by

Michael P. Angle and Jason Baker

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 on Plate 2.

Description of Map Symbols

Hydrogeologic Region → 7D24 ← Hydrogeologic Setting

170 ← Relative Pollution Potential

Legend

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

Roads
Streams
Lakes
Townships

Index Ranges

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

N

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

0 1 2 3 4 5
Miles

0 1 2 4 6 8
Kilometers

Ohio Department of Natural Resources
Division of Water
Ground Water Resources Section
1939 Fountain Square
Columbus Ohio 43224
www.dnr.state.oh.us

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