

**GROUND WATER POLLUTION POTENTIAL
OF GUERNSEY COUNTY, OHIO**

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ABSTRACT

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

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

Ground water pollution potential analysis in Guernsey County resulted in a map with symbols and colors that illustrate areas of varying ground water contamination vulnerability. Five hydrogeologic settings were identified in Guernsey County with computed ground water pollution potential indexes ranging from 56 to 153.

Guernsey County lies within the Nonglaciaded Central hydrogeologic setting. Yields in excess of 25 gallons per minute may be obtained from sand and gravel found in the buried valley deposits underlying Wills Creek west of Kimbolton and in the immediate vicinity of Pleasant City. Yields of 10 to 25 gallons per minute (gpm) are obtained from sand and gravel deposits of limited thickness and extent in valley fill found primarily along Wills Creek between Kimbolton and Cambridge, and along Birds Run. Yields of less than 3 to 10 gpm are obtained from wells drilled in fill along stream valleys consisting of clay with occasional thin lenses of sand and gravel. Yields vary based on the thickness and extent of the sand and gravel lenses.

The consolidated, bedrock aquifers throughout the county have yields that are quite variable. Overall, yields tend to be better adjacent to stream valleys and poorer along ridge tops. Yields from wells developed in the dirty sandstones, shales, siltstones, coals, and thin limestones of the Pennsylvanian Allegheny and Pottsville Groups usually range from 3 to 10 gpm. Yields obtained from wells drilled in the dirty sandstones, shales, claystones, and limestones of the Pennsylvanian Conemaugh Group and Monongahela Group typically have meager yields averaging less than 3 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 Guernsey County has been prepared to assist planners, managers, and local officials in evaluating the potential for contamination from various sources of pollution. This information can be used to help direct resources and land use activities to appropriate areas, or to assist in protection, monitoring, and clean-up efforts.

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INTRODUCTION

The need for protection and management of ground water resources in Ohio has been clearly recognized. Approximately 42 percent of Ohio citizens rely on ground water for drinking and household use from both municipal and private wells. Industry and agriculture also utilize significant quantities of ground water for processing and irrigation. In Ohio, approximately 750,000 rural households depend on private wells; 5,491 of these wells exist in Guernsey 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 Ohio Department of Natural Resources (ODNR), Division of Water (now Soil and Water Resources) 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 Soil and Water Resources, 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 Guernsey County has been prepared to assist planners, managers, and state and local officials in evaluating the relative vulnerability of areas to ground water contamination from various sources of pollution. This information can be used to help direct resources and land use activities to appropriate areas, or to assist in protection, monitoring, and clean-up efforts.

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

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

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

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

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

SUMMARY OF THE DRASTIC MAPPING PROCESS

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

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

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

Hydrogeologic Settings and Factors

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

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

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

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

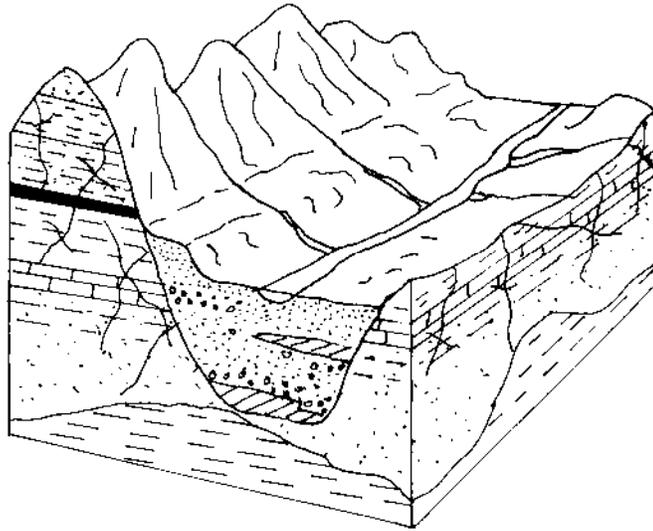
These factors incorporate concepts and mechanisms such as attenuation, retardation, and time or distance of travel of a contaminant with respect to the physical characteristics of the hydrogeologic setting. Broad consideration of these factors and mechanisms coupled with existing conditions in a setting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

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

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

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

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



7D Buried Valley

This hydrogeologic setting is limited to deposits found underlying Wills Creek and some of its tributaries, and Skull Fork. Broad, flat-lying floodplains and gently sloping terraces characterize the setting. Depths to water are typically less than 30 feet except in the deposits underlying Indian Camp Run and Bird Run. Depth to water in these tributaries can range up to 50 feet. 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. 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 higher permeability of the soils, vadose zone materials, and aquifer.

GWPP index values for the hydrogeologic setting of Buried Valley range from 104 to 153, with the total number of GWPP index calculations equaling 9.

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

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

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

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

Weighting and Rating System

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

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

Pesticide DRASTIC

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

Table 1. Assigned weights for DRASTIC features

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

Table 2. Ranges and ratings for depth to water

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

Table 3. Ranges and ratings for net recharge

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

Table 4. Ranges and ratings for aquifer media

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

Table 5. Ranges and ratings for soil media

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

Table 6. Ranges and ratings for topography

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

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

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

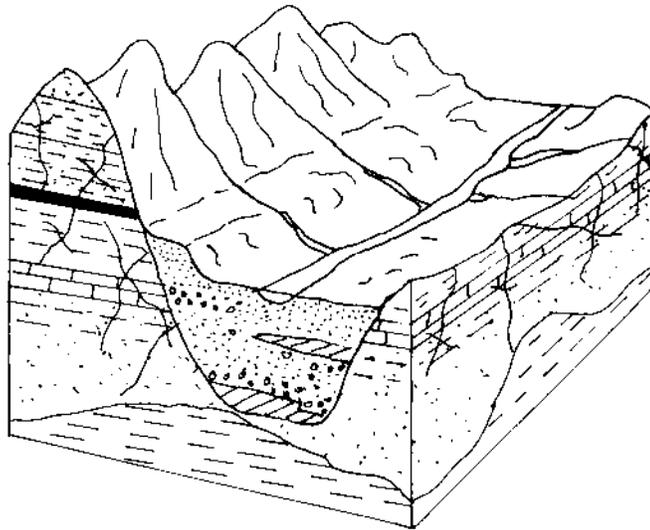
Table 8. Ranges and ratings for hydraulic conductivity

Hydraulic Conductivity (GPD/FT²)	
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 Guernsey 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 153. 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. Calculated pollution potential indexes for the 5 settings identified in Guernsey County range from 56 to 153.

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 Guernsey 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 Guernsey County is included with this report.



SETTING 7D1		GENERAL		
FEATURE	RANGE	WEIGHT	RATING	NUMBER
Depth to Water	5-15	5	9	45
Net Recharge	7-10	4	8	32
Aquifer Media	Sand & Gravel	3	7	21
Soil Media	Silty Loam	2	4	8
Topography	0-2%	1	10	10
Impact of Vadose Zone	Sand & Gravel w/Silt & Clay	5	5	25
Hydraulic Conductivity	300-700	3	4	12
		DRASTIC	INDEX	153

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
- 153 - defines the relative pollution potential

Here the first number (**7**) refers to the major hydrogeologic region and the upper case letters (**D**) refer to a specific hydrogeologic setting. The following number (**1**) references a certain set of DRASTIC parameters that are unique to this setting and are described in the corresponding setting chart. The second number (**153**) 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 GUERNSEY COUNTY

Demographics

Guernsey County occupies approximately 522 square miles in southeastern Ohio (Figure 3). Guernsey County is bounded to the north by Tuscarawas County, to the northeast by Harrison County, to the east by Belmont County, to the south by Noble County, to the west by Muskingum County, and to the northwest by Coshocton County.

The approximate population of Guernsey County, based upon 2012 estimates, is 39,817 (Department of Development, Ohio County Profiles, 2012). Cambridge is the largest community and the county seat. Forest is the major land use in the county. Agriculture is also an important land use, followed by pasture. Strip mining has historically been an important land use in the central and eastern portion of the county.

Climate

The *Hydrologic Atlas for Ohio* (Harstine, 1991) reports an average annual temperature of approximately 51 degrees Fahrenheit for Guernsey County. The average temperatures increase slightly towards the southwest and decrease slightly toward the southeast. The majority of the county receives about 40 inches per year of precipitation, but this amount increases somewhat in the southeastern portion of the county (Harstine, 1991). The mean annual precipitation for Cambridge is 39.16 inches per year based upon a thirty-year (1971-2000) period. The mean annual temperature at Cambridge for the same thirty-year period is 52.5 degrees Fahrenheit (U. S. Department of Commerce, 2002).

Physiography and Topography

Guernsey County lies entirely within the Allegheny Plateaus section of the Appalachian Plateaus Province (Frost, 1931, Fenneman, 1938, and Brockman, 1998). The northern third of the county lies within the Muskingum-Pittsburgh Plateau Region, while the remainder of the county lies within the Marietta Plateau Region. The Muskingum-Pittsburgh Plateau Region is characterized by moderately high to high relief, some broad river valleys with outwash terraces, and medium-grained bedrock sequences. High relief and rugged topography, featuring narrow ridges, steep slopes, a high degree of stream dissection, and fine-grained bedrock sequences are typical of the Marietta Plateau Region.

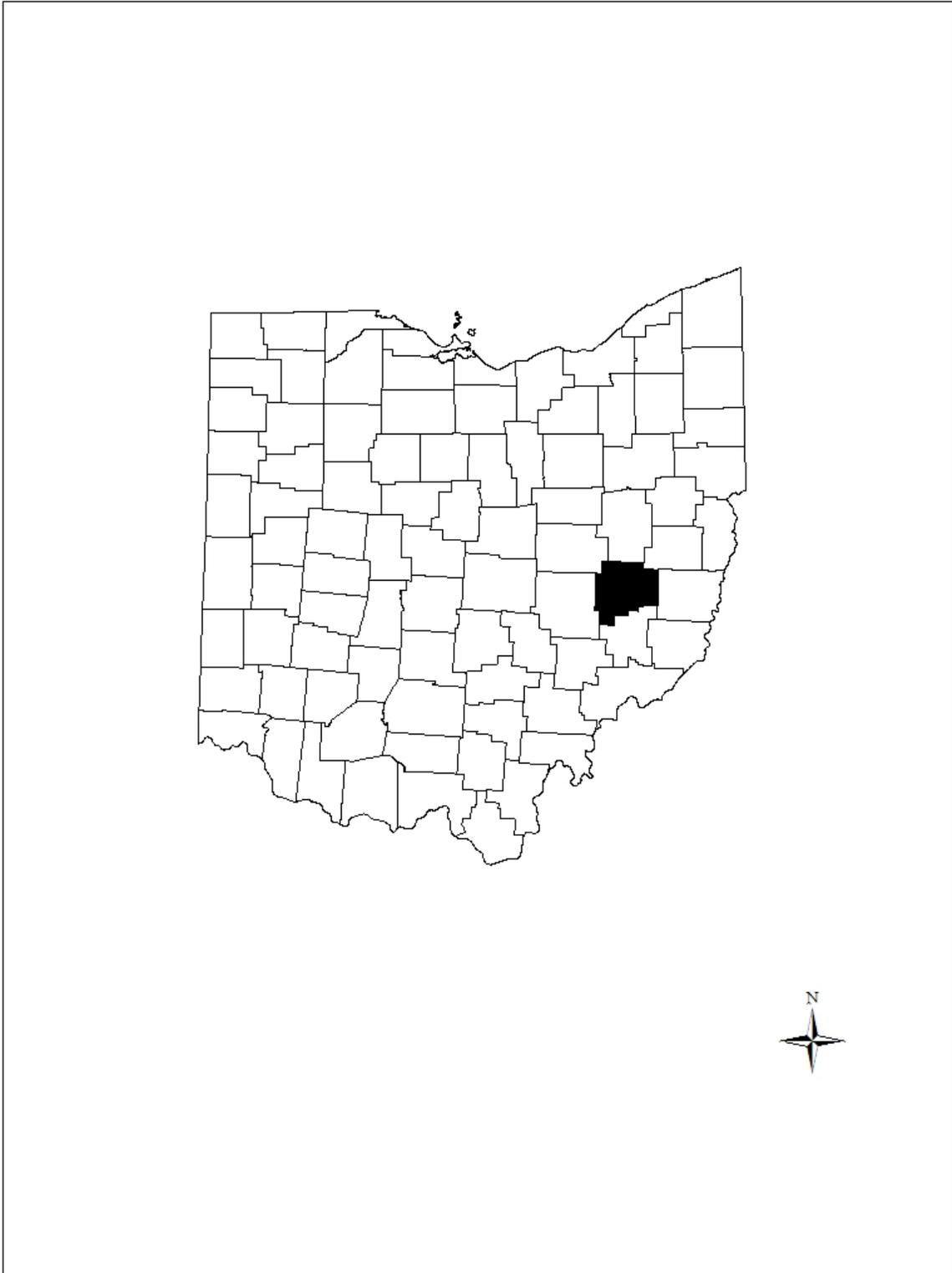


Figure 3. Location of Guernsey County, Ohio.

Modern Drainage

Wills Creek and its tributaries drain most of Guernsey County. Wills Creek flows to the north through central Guernsey County and then turns westward, emptying into the Muskingum River at the Muskingum County–Coshocton County boundary. Tributaries of Wills Creek with their headwaters in eastern Muskingum County include Buffalo Creek, Crooked Creek, Leatherwood Creek, Seneca Fork, and Salt Fork. The northeastern corner of the county is drained by the tributaries of Stillwater Creek, which then empties into the Tuscarawas River near Dennison.

Pre- and Inter-Glacial Drainage Changes

Guernsey County lies entirely beyond the glacial boundary; however, the drainage patterns of the county changed greatly as a result of the multiple glaciations. The drainage changes are complex and not yet fully understood. More research and data are necessary in both Guernsey County and adjacent counties.

Prior to glaciation, the Teays River System drained southeastern Ohio (Figure 4). The Cambridge River and its tributaries drained Guernsey County (Stout et al., 1943 and Stout, 1918). It flowed to the northwest following, in part, the present day course of Wills Creek. Eventually its course turned westward, emptying into the Groveport River near present day Newark. The Groveport River was an important eastern tributary of Teays River.

As ice advanced through Ohio during the pre-Illinoian (Kansan) glaciation, the Teays Drainage System was blocked. Flow backed-up in the main trunk of the Teays River Valley as well as in many tributaries, forming several large lakes. These lakes over-topped, creating spillways and cutting new channels. New drainage systems began to evolve (Stout et al., 1943). This downcutting by these new streams was believed to be relatively rapid and, in many places, the new channels were cut over 100 feet deeper than the previous Teays River System valleys. The new drainage system (Figure 5) is referred to as the Deep Stage due to this increased downcutting. A new trunk stream referred to as the Newark River down-cut and its headwaters eroded eastward, eventually extending to the city of Coshocton. Plainfield Creek, a northwesterly flowing tributary that closely followed the course of the Teays Stage Cambridge River, predominantly drained Guernsey County and joined the Newark River near West Lafayette. The divide (col) in northern Morgan County was still not breached at this time. During this time, the ancestral Ohio River became established.

The Illinoian ice advance brought further changes to the drainage systems (Figure 6). Opinions as to the nature of drainage changes as a result of the advancing Illinoian ice front differ. Stout et al. (1943) determined that Illinoian ice either did not advance into northeastern Ohio, or at least advanced at a different time than in western Ohio. As the Illinoian ice sheet advanced eastward from central Ohio, the Newark River was blocked in Licking County. The waters of the blocked drainage rose and eventually were diverted to the north; basically re-occupying the channel of the former Dover River. At this time, drainage to the north was possible, as advancing Illinoian ice did not block this area. This northerly flowing trunk stream was referred to as the Massillon River (Stout et al., 1943). Headwaters for Kimbolton Creek, a northwesterly-flowing tributary to the Ashcraft Creek (which in turn flowed into the Massillon River), drained most of Guernsey County. Lamborn (1956) and DeLong and White (1963) proposed that Illinoian ice did advance into northeastern Ohio and blocked drainage northward. They proposed that drainage was still primarily to the southwest through the Newark River.

The massive volumes of meltwater produced during the Wisconsin (most recent) ice advance eventually breached the col near Eagleport (Norling, 1958). This led to the establishment of the modern Muskingum River System (Stout et al., 1943 and Norling, 1958). Water drained from Guernsey County by Wills Creek and its tributaries reaches the Muskingum River northeast of Dresden at the Muskingum-Coshocton County line.

Glacial Geology

The majority of the glacially-related deposits are limited to the ancestral stream channels (Walker, 1991; Pavey et al., 1999; and ODNR, Division of Soil and Water Resources, Open File Glacial State Aquifer Map). Ancestral stream channels filled with glacial/alluvial sediments are referred to as buried valleys. The buried valleys are filled with differing sequences of coarse sand and gravel outwash, finer-grained lacustrine and modern, silty alluvial or floodplain deposits. These deposits vary with the energy level of the streams at that time. Streams leading away from melting glaciers are high energy and deposit coarser outwash. Outwash contains interbedded layers of sand and gravel deposited by a braided stream system. Streams that are blocked by ice or by thick channel deposits tend to be ponded and fill with finer-grained sediments. Modern tributaries, which lead into streams overlying the buried valleys, tend to contain variable thicknesses of sand, gravel, and silty alluvium.

Guernsey County also has many deposits of loess of appreciable thickness. Loess is a deposit formed by wind-blown silt. Loess is derived from the wind picking up fine silt-sized (to very fine-grained sand) particles covering the floodplains of the wide outwash or lacustrine valley floors. Loess is commonly found capping bedrock uplands and higher stream terraces to the east (upwind) of major river valleys. Deposits of loess up to 4 feet in thickness have been noted for Guernsey County. Loess is particularly important to the development of soils in these upland and terrace areas (Rubel et al., 2005).

Bedrock Geology

Bedrock exposed at the surface in Guernsey County belongs to the Pennsylvanian System. Table 9 summarizes the bedrock stratigraphy found in Guernsey County. The oldest rocks exposed in Guernsey County are part of the Allegheny and Pottsville Groups, and are found in the northwest corner and west-central portion of the county. These Pennsylvanian rocks include interbedded dirty sandstones, shales, siltstones, and thin limestones and coals. Rocks of the Conemaugh Group are exposed in much of the western, central, and eastern part of the county. These rocks include interbedded dirty, micaceous sandstones, shales, siltstones, thin, fine-grained limestones, and minor coals. Higher in the section, the rocks tend to include more fine-grained mudstones and claystones (Collins, 1979). Rocks of the Monongahela Group are found mostly in the southeastern and southwestern corners of Guernsey County. These rocks include interbedded dirty sandstones, shales, minor limestones, and some important coal beds.

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.

Sandstones and shales represent deltaic/shoreline environments in the Allegheny and Pottsville Groups. Marine limestones formed in slightly deeper waters, which lacked clastic input from rivers and deltas. Coal and clay were deposited in two different environments. Coal was deposited in either a "back-barrier" environment along the shoreline or in "deltaic-plain" environment in swamps formed in abandoned river channels (Horne et al., 1978). Similarly, clay was deposited in either quiet lagoonal areas directly behind the shoreline or in abandoned "oxbow" river channels (Ferm, 1974).

Table 9. Bedrock stratigraphy of Guernsey County, Ohio (after Slucher et al., 2006)

System	Group/Formation (Symbol)	Lithologic Description
Pennsylvanian	Monongahela Group (Pm)	Red, gray, green, purple, yellow to black interbedded shale, siltstone, sandstone, mudstone, limestone and coal. Shale, siltstone, sandstone, and mudstone clayey to silty, and locally calcareous. Mudstones subject to severe surface weathering, landslides common where unit crops out. Unit contains economic coal beds.
	Conemaugh Group (Pc)	Red, gray, green, purple, yellow to black interbedded shale, siltstone, sandstone, mudstone, limestone and coal. Shale, siltstone, sandstone, and mudstone clayey to silty, and locally calcareous. Marine shale, limestone, and/or flinty limestone intervals common in lower one-half of unit; non-marine limestone intervals mostly in upper one-half of unit. Coal bed are thin and rarely economic.
	Allegheny and Pottsville Groups, undifferentiated (Pap)	Gray to black shale, siltstone, sandstone, conglomerate, limestone, underclay, coal, and flint. Sandstone is silty to pebbly, locally quartzose and/or conglomeratic in lower one-third of unit, particularly the Sharon Conglomerate.

Ground Water Resources

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

Yields greater than 25 gpm are obtainable from the interbedded and inter-lensing deposits of sand, gravel, silt and clay found in the valley of Wills Creek near Pleasant City and northwest of Kimbolton (Walker, 1991 and ODNR, Division of Soil and Water Resources 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 high sustainable yields capable from these larger diameter wells. Smaller diameter wells should be suitable for serving domestic/farm needs within this aquifer.

Yields of 10 to 25 gpm are obtained from sand and gravel deposits of limited thickness and extent in valley fill. These deposits are found primarily along Wills Creek between Kimbolton and Cambridge, and along Birds Run. Yields of less than 3 to 10 gpm are obtained from wells drilled in fill along stream valleys consisting of clay with occasional thin lenses of sand and gravel (Walker, 1991 and ODNR, Division of Soil and Water Resources, Open File Glacial State Aquifer Map). Yields vary based on the thickness and extent of the sand and gravel lenses.

Yields from the consolidated, bedrock aquifers throughout the county are variable. Overall, yields tend to be better adjacent to stream valleys and poorer along ridge tops. Yields from wells developed in the dirty sandstones, shales, siltstones, coals, and thin limestones of the Allegheny and Pottsville Groups usually range from 3 to 10 gpm. Yields obtained from wells drilled in the dirty sandstones, shales, claystones, and limestones of the Conemaugh Group and Monongahela Group typically have meager yields averaging less than 3 gpm (Walker, 1991 and ODNR, Division of Soil and Water Resources, Open File Bedrock State Aquifer Map).

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

The number of fractures and bedding planes intersected by the well also influences yields. The amount of fracturing tends to be greater in the valley bottoms than at the ridge tops. This

increase may be related to stress relief, as shown by Wyrick and Borchers (1981) and Kipp et al. (1983). The net result is that there is usually a decrease in the depth to water (i.e. a shallower static water level) and slightly higher yields. Fracturing is also an influence on the direction of ground water flow (Schubert, 1980) and affects the amount of recharge.

Strip and Underground Mined Areas

The pollution potential of strip-mined, and abandoned/active underground mined areas was not evaluated in Guernsey 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. DRASTIC parameters and the possible impacts that mining may have on rating the parameters in strip-mined and underground mined areas are listed in Tables 10 and 11. 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/active 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 Guernsey County. Delineations of mined areas were made using information from the *Soil Survey of Guernsey County* (Rubel et al., 2005), abandoned underground mine maps (ODNR, Division of Geological Survey), and the Guernsey 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)

REFERENCES

- Aller, L., T. Bennett, J.H. Lehr, R.J. Petty, and G. Hackett, 1987. DRASTIC: A standardized system for evaluating ground water pollution potential using hydrogeological settings. U.S. Environmental Protection Agency EPA/600/2-87-035, 622 pp.
- Angle, M.P. and J. Baker, 2001. Ground water pollution potential of Tuscarawas County, Ohio. Ohio Department of Natural Resources, Division of Water, GWPP Report No. 52.
- Angle, M.P. and J. Jonak, 2001. Ground water pollution potential of Morgan County, Ohio. Ohio Department of Natural Resources, Division of Water, GWPP Report No. 53.
- Angle, M.P. and M. Akins, 2001. Ground water pollution potential of Muskingum County, Ohio. Ohio Department of Natural Resources, Division of Water, GWPP Report No. 54.
- Angle, M.P. and J. Jonak, 2002. Ground water pollution potential of Belmont County, Ohio. Ohio Department of Natural Resources, Division of Water, GWPP Report No. 50.
- Angle, M.P., D. Walker, and J. Jonak, 2002. Ground water pollution potential of Washington County, Ohio. Ohio Department of Natural Resources, Division of Water, GWPP Report No. 55.
- Angle, M.P. and D. Walker, 2002. Ground water pollution potential of Harrison County, Ohio. Ohio Department of Natural Resources, Division of Water, GWPP Report No. 56.
- Bonta, J.V., C.R. Amerman, W.A. Dick, G.F. Hall, T.J. Harlukowicz, A.C. Razem, and N.E. Smeck, 1992. Impact of surface coal mining on three Ohio watersheds – physical conditions and groundwater hydrology. Water Resources Bulletin, Volume 28, Number 3, PP. 577-596.
- Bork, K.B. and R.J. Malcuit, 1987. Black Hand Gorge State Nature Preserve: Lower Mississippian deltaic deposits in east central Ohio. Geological Society of America Centennial yield Guide – North Central Section, pp. 411-414.
- Brockman, C.S., 1998. Physiographic regions of Ohio. Ohio Department of Natural Resources, Division of Geological Survey, map with text.
- Carney, F., 1907. The glacial dam at Hanover, Ohio. Bulletin, Science Laboratory, Dennison University, vol. 13, pp. 139-153.

- Collins, H.R., 1979. The Mississippian and Pennsylvanian (Carboniferous) systems in the United State-Ohio. U.S. Geological Survey Professional Paper 1110-E, 25 pp.
- DeLong, R.M. and G.W. White, 1963. Geology of Stark County. Ohio Department of Natural Resources, Division of Geological Survey, Bulletin 61, 209 pp.
- Dove, G.D., 1960. Water resources of Licking County, Ohio. Ohio Department of Natural Resources, Division of Water, Bulletin 36, 96 pp.
- Driscoll, F.G., 1986. Groundwater and wells. Johnson Filtration Systems, St. Paul, Minnesota, 1089 pp.
- Fenneman, N.M., 1938. Physiography of the eastern United States. McGraw-Hill Book Co., New York, New York, 714 pp.
- Ferm, J.C., 1974. Carboniferous environmental models in eastern United States and their significance. In G. Briggs, ed. Carboniferous of the southern United States. Geological Society of America Special Paper 148.
- Fetter, C.W., 1980. Applied hydrogeology. Charles E. Merrill Publishing Co., Columbus, Ohio, 488 pp.
- Forsyth, J.L., 1966. Glacial map of Licking County, Ohio. Ohio Department of Natural Resources, Division of Geological Survey, Report of Investigations No. 59, map with text.
- Freeze, R.A. and J.A. Cherry, 1979. Ground water. Prentice-Hall, Englewood Cliffs, New Jersey, 604 pp.
- Frost, R.B., 1931. Physiographic map of Ohio. Oberlin College, The Geographical Press, Columbia University, New York, New York, map with text.
- Goldthwait, R.P., G.W. White, and J.L. Forsyth, 1961. Glacial map of Ohio. U.S. Geological Survey, Miscellaneous Geologic Investigations Map I-316.
- Harstine, L.J., 1991. Hydrologic atlas for Ohio. Ohio Department of Natural Resources, Division of Water, Water Inventory Report, No. 28, 13 pp.
- Heath, R.C., 1984. Ground-water regions of the United States. U.S. Geological Survey, Water Supply Paper 2242, 78 pp.

- Horne, J.C., J.C. Ferm, F.T. Carrucio, and B.P. Baganz, 1978. Depositional models in coal exploration and mine planning in Appalachian region. American Association of Petroleum Geologists Bulletin, Vol. 62, No. 12, pp.2379-2411.
- Kipp, J.A., F.W. Lawrence, and J.S. Dinger, 1983. A conceptual model of ground-water flow in the eastern Kentucky coal field. 1983 Symposium on Surface Mining, Hydrology, Sedimentology, and Reclamation. University of Kentucky, Lexington, Kentucky, pp. 543-548.
- Lamborn, R.E., 1951. Limestones of eastern Ohio. Ohio Department of Natural Resources, Division of Geological Survey, Bulletin 49, 377 pp.
- Lamborn, R.E., 1956. Geology of Tuscarawas County. Ohio Department of Natural Resources, Division of Geological Survey, Bulletin 55, 269 pp.
- Norling, D.L., 1958. Geology and mineral resources of Morgan County, Ohio. Ohio Department of Natural Resources, Division of Geological Survey, Bulletin 56, 131 pp.
- Ohio Department of Natural Resources, Division of Geological Survey, Open File, Reconnaissance Bedrock Geology Maps. Available on a U.S.G.S. 7-1/2 minute quadrangle basis.
- Ohio Department of Natural Resources, Division of Water, 1985. Principal streams and their drainage areas. Map, 1 pp.
- Ohio Department of Natural Resources, Division of Water, Open File Bedrock State Aquifer Maps. Available on a U.S.G.S. 7-1/2 minute quadrangle basis.
- Ohio Department of Natural Resources, Division of Water, Open File Glacial State Aquifer Maps. Available on a U.S.G.S. 7-1/2 minute quadrangle basis.
- Owenby, J.R. and D.S. Ezell, 1992. Monthly station normals of temperature, precipitation, and heating and cooling degree days, 1961-1990. Climatography of the United States No. 81, OHIO. U.S. Department of the Interior, Project A-051-OHIO, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, 30 pp.
- Pavey, R.R., R.P. Goldthwait, C.S. Brockman, D.N. Hull, E.M. Swinford, R.G. Van Horn, 1999. Quaternary geology of Ohio. Ohio Department of Natural Resources, Division of Geological Survey, Map, No. 2, map with text.
- Peffer, J.R., 1991. Complex aquifer-aquitard relationships at an Appalachian Plateau site. Ground Water, Vol. 29, No.2, pp.209-217.

- Pettyjohn, W.A. and R. Henning, 1979. Preliminary estimate of ground-water recharge rates, related streamflow and water quality in Ohio. U.S. Department of the Interior, Project A-051-OHIO, Project Completion Report No. 552, Water Resources Center, The Ohio State University, Columbus, Ohio, 323 pp.
- Razem, A.C., 1983. Ground-water hydrology before, during, and after coal strip mining of a small watershed in Jefferson County, Ohio. U.S. Geological Survey, Water Resources Investigations Report 83-4215, 36 pp.
- Rubel, N., J. Glanville, and R. Griffin, 2004. Soil survey of Guernsey County, Ohio. U.S. Department of Agriculture, Natural Resources Conservation Service, 434 pp.
- Schubert, J.P., 1980. Fracture flow of groundwater in coal-bearing strata. Symposium on Surface Mining, Hydrology, Sedimentology, and Reclamation, University of Kentucky, Lexington, Kentucky, pp. 61-73.
- Slucher, E.R., (principal compiler), Swinford, E.M., Larsen, G.E., and others, with GIS production and cartography by Powers, D.M., 2006. Bedrock geologic map of Ohio. Ohio Division of Geological Survey Map BG-1, version 6.0, scale 1:500,000.
- Spahr, P.N., 1995. Ground water pollution potential of Coshocton County, Ohio. Ohio Department of Natural Resources, Division of Water, GWPP Report No. 32, 74 pp.
- Stout W., K. Ver Steeg, and G.F. Lamb, 1943. Geology of water in Ohio. Ohio Department of Natural Resources, Division of Geological Survey, Bulletin 44, 694 pp.
- U.S. Department of Commerce, 2002. Monthly normals of temperature, precipitation and heating and cooling degree days 1971-2000 Ohio. National Oceanic and Atmospheric Administration, National Climatic Data Center, Climatology of the United States, No. 81 (by state) 16 pp.
- Walker, A.C., 1991. Ground water resources of Guernsey County. Ohio Department of Natural Resources, Division of Water, Ground Water Resources Map, map with text.
- Weedman, S.D., 1990. Freshwater limestones of the Allegheny Group. Pennsylvania Geology, Vol. 21, No. 1, pp. 9-16.
- Wyrick, G.G. and J.W. Borchers, 1981. Hydrologic effects of stress-relief fracturing in an Appalachian valley. U.S. Geological Survey, Water Supply Paper 2177, 51 pp.

UNPUBLISHED/ONLINE DATA

Ohio Department of Development, Office of Policy, Research, and Strategic Planning. Ohio county profiles, 2012.

Ohio Department of Natural Resources, Division of Soil and Water Resources. Water well log and drilling reports for Guernsey County.

Ohio Department of Natural Resources, Division of Geological Survey. Ohio Mines, 2013. <http://www2.dnr.state.oh.us/website/geo/mines/>

Ohio Department of Natural Resources, Division of Geological Survey. Active Mineral Industries Locations, 2013. <https://gis.ohiodnr.gov/website/dgs/industrialminerals/>

Ohio Statewide Imagery Program. Digital elevation model for Guernsey County, Ohio, 2013. <http://geospatial.ohiodnr.gov/>

United States Department of Agriculture, Natural Resource Conservation Service. Soil Data Mart OH059-Guernsey County, Ohio, 2013. <http://datagateway.nrcs.usda.gov>

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 Soil and Water Resources. Approximately 5,491 water well log records are on file for Guernsey County. Static water levels and information as to the depths at which water was encountered were taken from roughly 2,600 of these records. The *Ground Water Resources of Guernsey County* (Walker, 1991) provided generalized depth to water information throughout the county. Depth to water trends mapped in adjoining Morgan County (Angle et al., 2001) Coshocton County (Spahr, 1995), Washington County (Angle et al., 2002), Muskingum County (Angle et al., 2001), Tuscarawas County (Angle et al., 2001), Harrison County (Angle et al., 2002), and Belmont County (Angle et al., 2002) were helpful. Topographic and geomorphic trends were utilized in areas where other sources of data were lacking.

Depths to water of 5 to 15 feet (DRASTIC rating = 9) were typical of areas immediately adjacent to Wills Creek 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 many moderately sloping areas. 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 runoff. This factor was evaluated using many criteria, including depth to water, topography, soil type, surface drainage, vadose zone material, aquifer type, and annual precipitation. General estimates of recharge provided by Pettyjohn and Henning (1979) proved to be helpful.

Values of 7 to 10 inches per year (8) were assigned to limited areas of the buried valley underlying Wills Creek near the Coshocton County border. These areas contain highly permeable soils, vadose, and aquifer materials, have shallow depths to water, gentle slopes, and surficial streams, and are limited to terraces and floodplains underlain by coarse-grained outwash deposits. Values of 4 to 7 inches per year (6) were used for areas with moderate recharge. These areas include most of the buried valley areas, as well as 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.

Aquifer Media

Information on aquifer media was obtained from the reports of Stout et al. (1943) and Walker (1991). Mapping in adjoining Morgan County (Angle et al., 2001) Coshocton County (Spahr, 1995), Washington County (Angle et al., 2002), Muskingum County (Angle et al., 2001), Tuscarawas County (Angle et al., 2001), Harrison County (Angle et al., 2002), and Belmont County (Angle et al., 2002) proved useful as a guideline for evaluating aquifers. Open File Bedrock Reconnaissance Maps based upon U.S.G.S. 7-1/2 minute topographic maps from the ODNR, Division of Geological Survey proved helpful. The ODNR, Division of Soil and Water Resources Glacial State Aquifer Map and Bedrock State Aquifer Map were important sources of aquifer data. Water well log and drilling report records on file at the ODNR, Division of Soil and Water Resources, were the primary source of aquifer information.

Aquifer ratings of (5), (6), and (7) were selected for sand and gravel deposits found underlying Wills Creek and its tributary streams and valleys. The lower-rated sand and gravel aquifers tend to be thinner, are moderately-sorted and are finer-grained than the clean, higher-rated sand and gravel deposits found in certain areas of the buried valley under Wills Creek and Skull Fork. Typically the lower-rated sand and gravel lenses were interbedded with thicker sequences of fine-grained alluvial or lacustrine deposits.

An aquifer rating of (4) was used for interbedded sandstones and shales of the Pennsylvanian Pottsville and Allegheny Group. An aquifer rating of (3) was used for the poor aquifers associated with the Pennsylvanian undivided (Monongahela and Conemaugh Groups).

Soils

Soils were mapped using the data obtained from the *Soil Survey of Guernsey County* (Rubel et al., 2005) and the USDA Natural Resource Conservation Service Geospatial Data Gateway website. 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. Table 12 is a list of the soils, parent materials, setting, and corresponding DRASTIC values for Guernsey County.

Table 12. Guernsey County soils

Soil Name	Parent Material/Setting	DRASTIC Rating	Soil Media
Aaron	Residuum on slopes	7	Shrink/swell clay
Aaron-Upshur	Residuum on slopes	7	Shrink/swell clay
Allegheny	Alluvium on terraces	4	Silty loam
Barkcamp	Coal extraction mine spoils	NR	
Berks	Shale and sandstone slopes	10	Thin/Absent
Bethesda	Coal extraction mine spoils	NR	
Brookside	Fine colluvium	7	Shrink/swell clay
Brookside-Vandalia	Colluvium	7	Shrink/swell clay
Chagrin	Alluvium on floodplains	4	Silty loam
Clarksburg*	Colluvium	3	Clay loam
Claysville-Guernsey	Colluvium	7	Shrink/swell clay
Coshocton	Colluvium over residuum	3	Clay loam
Dekalb	Residuum	7	Shrink/swell clay
Dumps, mine	Strip mine	NR	
Elba	Residuum	7	Shrink/swell clay
Elba-Berks	Residuum	10	Thin/Absent
Enoch	Coal extraction mine spoil	NR	
Euclid	Alluvium on terraces	4	Silty loam
Fairpoint	Coal extraction mine spoil	NR	
Fitchville	Lacustrine deposits	4	Silty loam
Gilpin	Residuum	10	Thin/Absent
Glenford	Lacustrine deposits	4	Silty loam
Guernsey	Colluvium over residuum	7	Shrink/swell clay
Guernsey-Upshur	Fine-grained bedrock	7	Shrink/swell clay
Hazelton	Residuum	6	Sandy loam
Hartshorn	Alluvium on floodplains	6	Sandy loam
Holton	Alluvium on floodplains	4	Silty loam
Kanawha	Alluvium on terraces	4	Silty loam
Keene*	Loess over residuum	3	Clay loam
Linside	Alluvium on floodplains	4	Silty loam
Lobdell	Alluvium on floodplains	4	Silty loam
Lowell	Residuum	7	Shrink/swell clay
Lowell-Gilpin	Residuum	10	Thin/Absent
Lowell-Upshur	Residuum	7	Shrink/swell clay
Lowell-Westmoreland	Residuum	3	Clay loam
McGary	Lacustrine on terraces	7	Shrink/swell clay
Melvin	Alluvium on floodplains	4	Silty loam
Mentor	Lacustrine on terraces	4	Silty loam
Morristown	Coal extraction mine spoil	NR	
Newark	Alluvium on floodplains	4	Silty loam
Nolin	Alluvium on floodplains	4	Silty loam
Omulga*	Loess over alluvium over lacustrine	3	Clay loam
Orrville	Alluvium on floodplains	5	Loam
Richland	Colluvium	5	Loam
Sarahsville	Lacustrine on floodplains	7	Shrink/swell clay
Sees	Colluvium	3	Clay loam
Upshur	Residuum	7	Shrink/swell clay
Urban land – Glenford	Lacustrine	4	Silty loam
Urban land – Mentor	Lacustrine on terraces	4	Silty loam
Urban land – Westmoreland	Bedrock residuum	4	Silty loam
Vandalia	Colluvium	7	Shrink/swell clay
Vincent	Lacustrine on terraces	7	Shrink/swell clay
Wellston	Residuum	4	Silty loam
Westmore	Loess over residuum	7	Shrink/swell clay
Westmoreland	Bedrock residuum	4	Silty loam
Westmoreland-Berks	Bedrock residuum	10	Thin/Absent
Westmoreland-Dekalb	Bedrock residuum	10	Thin/Absent
Woodsfield	Loess over bedrock residuum	7	Shrink/swell clay
Zanesville	Loess over bedrock residuum	4	Silty loam
Zipp	Lacustrine deposits on floodplains	7	Shrink/swell clay

* denotes soils containing fragipan

Soils were considered to be Thin/Absent (10) along many steep ridge tops and slopes where bedrock was exposed. Shrink-swell clays (7) were rated for upland areas having very clayey shale and mudstone bedrock residuum. Sandy loam soils (6) were selected for residual sandstone ridges in the northwestern corner of the county, as well as some alluvial deposits in tributary valleys. Loam (5) was chosen for some soils on gentle slopes along smaller tributaries. Silt loam (4) soils were evaluated for silty shale and siltstone residuum on slopes and ridge tops and also for silty alluvial and lacustrine deposits on floodplains. Silt loam (4) was selected for soils developed on the loess-capped uplands and terraces. Clay loam (3) soils were evaluated for fine-grained bedrock residuum as well as finer-grained alluvial deposits in floodplains.

Certain soils in Guernsey 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 digital elevation model for Guernsey County (Ohio Geographically Referenced Information Program, 2013). Slopes of 0 to 2 percent (10) and 2 to 6 percent (9) were selected for flat-lying floodplains, valley floors, and terraces. Slopes of 2 to 6 percent (9) and 6 to 12 percent (5) used for gentler, more rounded ridge tops. Slopes of 6 to 12 percent (5) were also used for less steep ridges, typically those flanking broader valleys and in areas with less resistant bedrock types. Slopes of 12 to 18 percent (3) and greater than 18 percent (1) were selected for steeper slopes in high relief, upland areas.

Impact of the Vadose Zone Media

Information on vadose zone media was obtained from the reports of Stout et al. (1943), Stout (1918), and Walker (1992). Mapping in adjoining Morgan County (Angle et al., 2001) Coshocton County (Spahr, 1995), Washington County (Angle et al., 2002), Muskingum County (Angle et al., 2001), Tuscarawas County (Angle et al., 2001), Harrison County (Angle et al., 2002), and Belmont County (Angle et al., 2002) proved useful as a guideline for evaluating aquifers. Open File Bedrock Reconnaissance Maps based upon U.S.G.S. 7-1/2 minute topographic maps from the ODNR, Division of Geological Survey proved helpful. The ODNR, Division of Soil and Water Resources Glacial State Aquifer Map and Bedrock State Aquifer Map were important sources of vadose zone data. Water well log and drilling report records on file at the ODNR, Division of Soil and Water Resources were the primary source of vadose zone information. Information on parent materials derived from the *Soil Survey of Guernsey County* (Rubel et al., 2005), also proved useful in evaluating vadose zone materials.

Vadose zone media was given ratings of (5) and (6) for sand and gravel interbedded with silt and clay layers for the buried valley underlying Wills Creek and portions of Skull Fork. These ratings depend upon the proportion of sand and gravel to the finer-grained alluvial and lacustrine deposits. Silt and clay with ratings of (3), (4) and (5) were selected for vadose zone media for floodplains in many tributary valleys.

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

Hydraulic Conductivity

Published data for hydraulic conductivity for Guernsey County was found lacking. Information from Walker (1991), the ODNR, Division of Soil and Water Resources Glacial State Aquifer Map and Bedrock State Aquifer Map, as well as water well log and drilling report records on file at the ODNR, Division of Soil and Water Resources, were the primary sources of information. Hydraulic conductivity values utilized in adjoining Morgan County (Angle et al., 2001) Coshocton County (Spahr, 1995), Washington County (Angle et al., 2002), Muskingum County (Angle et al., 2001), Tuscarawas County (Angle et al., 2001), Harrison County (Angle et al., 2002), and Belmont County (Angle et al., 2002) 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.

The aquifers with an aquifer rating of (6) or (7) were given a hydraulic conductivity values of 300-700 gallons per day per square foot (gpd/ft²) (4). These values were limited to sand and gravel deposits in the buried valley underlying Wills Creek and Skull Fork. For sand and gravel deposits along the margins of the buried valley and in tributaries, hydraulic conductivities of 100-300 gpd/ft² (2) were used. In these deposits, thin sand and gravel lenses were interbedded with finer-grained materials.

All of the bedrock aquifers in Guernsey County were evaluated as having hydraulic conductivity values ranging from 1-100 gpd/ft² (1) due to the overall low permeability of these interbedded sedimentary rocks.

APPENDIX B

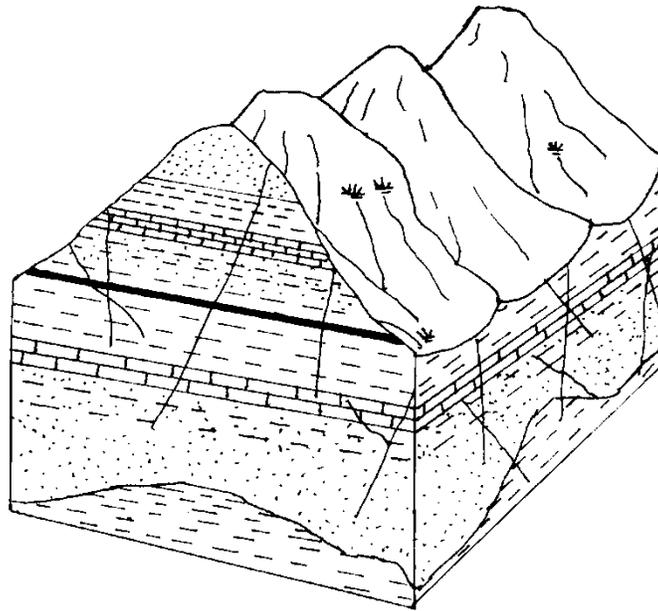
DESCRIPTION OF HYDROGEOLOGIC SETTINGS AND CHARTS

Ground water pollution potential mapping in Guernsey County resulted in the identification of 5 hydrogeologic settings within the Glaciated and Nonglaciated Central Region. The list of these settings, the range of pollution potential index calculations, and the number of index calculations for each setting are provided in Table 13. Computed Pollution potential indexes computed for Guernsey County range from 56 to 153.

Table 13. Hydrogeologic settings mapped in Guernsey County, Ohio

Hydrogeologic Settings	Range of GWPP Indexes	Number of Index Calculations
6Da - Alternating Sandstone, Limestone, Shale-Thin Regolith	56-105	56
6Fa-River Alluvium With Overbank Deposits	107-124	7
6Fb - River Alluvium Without Overbank Deposits	97-122	17
7D - Buried Valley	104-153	9
7Fa - Glacial Lakes and Slackwater Terraces	94-136	11

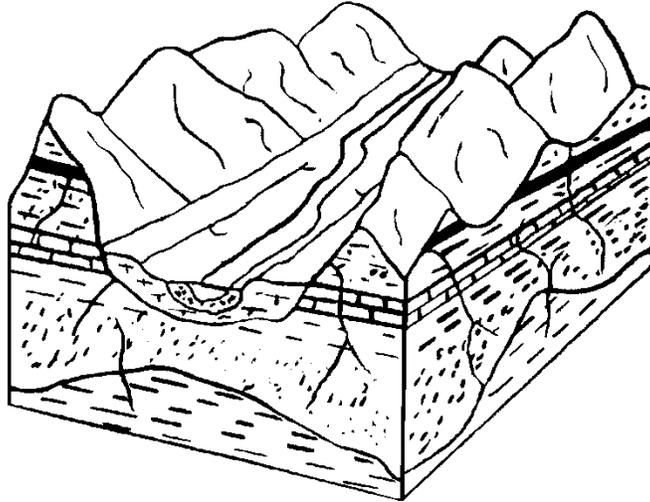
The following information provides a description of each hydrogeologic setting identified in the county, a block diagram illustrating the characteristics of the setting, and a listing of the charts for each unique combination of pollution potential indexes calculated for each setting. The charts provide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



6Da Alternating Sandstone, Limestone, Shale – Thin Regolith

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

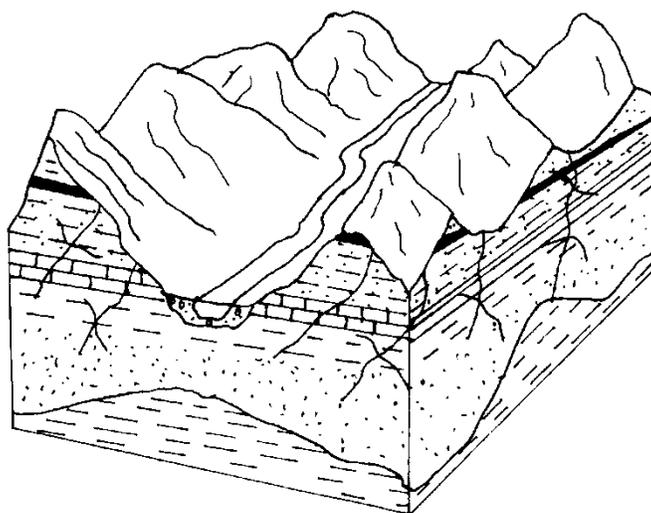
GWPP index values for the hydrogeologic setting of Alternating Sandstone, Limestone, Shale – Thin Regolith range from 56 to 105, with the total number of GWPP index calculations equaling 56.



6Fa River Alluvium with Overbank Deposits

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

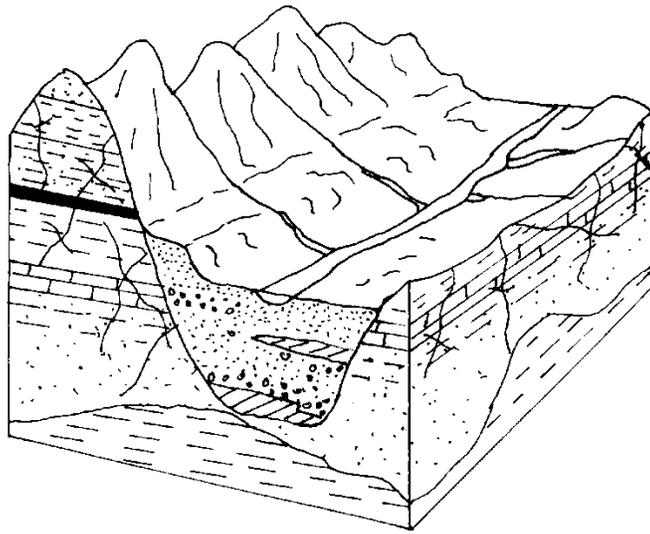
GWPP index values for the hydrogeologic setting of River Alluvium with Overbank Deposits range from 107 to 124, with the total number of GWPP index calculations equaling 7.



6Fb River Alluvium without Overbank Deposits

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

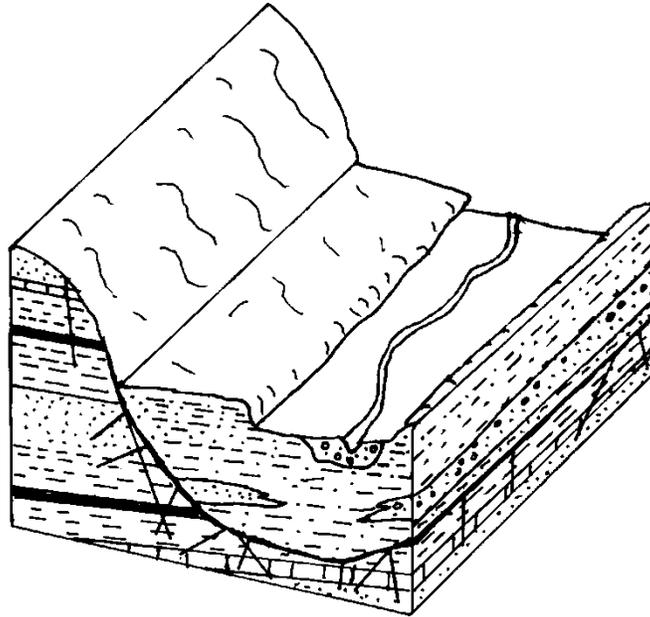
GWPP index values for the hydrogeologic setting of River Alluvium without Overbank Deposits range from 97 to 122, with the total number of GWPP index calculations equaling 17.



7D Buried Valley

This hydrogeologic setting is limited to deposits found underlying Wills Creek and some of its tributaries, and Skull Fork. Broad, flat-lying floodplains and gently sloping terraces characterize the setting. Depths to water are typically less than 30 feet except in the deposits underlying Indian Camp Run and Bird Run. Depth to water in these tributaries can range up to 50 feet. 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. 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 higher permeability of the soils, vadose zone materials, and aquifer.

GWPP index values for the hydrogeologic setting of Buried Valley range from 104 to 153, with the total number of GWPP index calculations equaling 9.



7Fa Glacial Lakes and Slackwater Terraces

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

GWPP index values for the hydrogeologic setting of Glacial Lakes and Slackwater Terraces range from 94 to 136, with the total number of GWPP index calculations equaling 11.

Table 14. Hydrogeologic Settings, DRASTIC Factors, and Ratings

Setting	Depth to Water(ft)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% slope)	Vadose Zone Media	Hydraulic Conductivity	Rating	Pesticide Rating
6Da1	75-100	2-4	Interbedded sst/sh/lst/coal	Thin/Absent Gravel	12-18	Interbedded sst/sh/lst/coal	1-100	72	104
6Da2	50-75	2-4	Interbedded sst/sh/lst/coal	Thin/Absent Gravel	18+	Interbedded sst/sh/lst/coal	1-100	75	103
6Da3	75-100	2-4	Interbedded sst/sh/lst/coal	Shrink/Swell Clay	6-12	Interbedded sst/sh/lst/coal	1-100	68	95
6Da4	75-100	2-4	Interbedded sst/sh/lst/coal	Clay Loam	2-6	Interbedded sst/sh/lst/coal	1-100	64	87
6Da5	75-100	2-4	Interbedded sst/sh/lst/coal	Shrink/Swell Clay	12-18	Interbedded sst/sh/lst/coal	1-100	66	89
6Da6	75-100	2-4	Interbedded sst/sh/lst/coal	Silty Loam	2-6	Interbedded sst/sh/lst/coal	1-100	66	92
6Da7	75-100	2-4	Interbedded sst/sh/lst/coal	Thin/Absent Gravel	2-6	Interbedded sst/sh/lst/coal	1-100	78	122
6Da8	75-100	2-4	Interbedded sst/sh/lst/coal	Clay Loam	6-12	Interbedded sst/sh/lst/coal	1-100	60	75
6Da9	30-50	2-4	Interbedded sst/sh/lst/coal	Clay Loam	12-18	Interbedded sst/sh/lst/coal	1-100	73	84
6Da10	75-100	2-4	Interbedded sst/sh/lst/coal	Thin/Absent Gravel	6-12	Interbedded sst/sh/lst/coal	1-100	74	110
6Da11	50-75	0-2	Interbedded sst/sh/lst/coal	Thin/Absent Gravel	18+	Interbedded sst/sh/lst/coal	1-100	67	95
6Da12	75-100	2-4	Interbedded sst/sh/lst/coal	Sandy Loam	18+	Interbedded sst/sh/lst/coal	1-100	62	78
6Da13	50-75	2-4	Interbedded sst/sh/lst/coal	Clay Loam	18+	Interbedded sst/sh/lst/coal	1-100	61	68
6Da14	50-75	2-4	Interbedded sst/sh/lst/coal	Silty Loam	2-6	Interbedded sst/sh/lst/coal	1-100	71	97
6Da15	75-100	2-4	Interbedded sst/sh/lst/coal	Shrink/Swell Clay	2-6	Interbedded sst/sh/lst/coal	1-100	72	107
6Da16	30-50	2-4	Interbedded sst/sh/lst/coal	Clay Loam	2-6	Interbedded sst/sh/lst/coal	1-100	79	102
6Da17	50-75	2-4	Interbedded sst/sh/lst/coal	Thin/Absent Gravel	2-6	Interbedded sst/sh/lst/coal	1-100	83	127
6Da18	30-50	4-7	Interbedded sst/sh/lst/coal	Clay Loam	12-18	Interbedded sst/sh/lst/coal	1-100	85	96
6Da19	50-75	2-4	Interbedded sst/sh/lst/coal	Clay Loam	6-12	Interbedded sst/sh/lst/coal	1-100	65	80
6Da20	30-50	2-4	Interbedded sst/sh/lst/coal	Clay Loam	2-6	Interbedded sst/sh/lst/coal	1-100	79	102
6Da21	30-50	2-4	Interbedded sst/sh/lst/coal	Clay Loam	6-12	Interbedded sst/sh/lst/coal	1-100	75	90
6Da22	50-75	2-4	Interbedded sst/sh/lst/coal	Clay Loam	12-18	Interbedded sst/sh/lst/coal	1-100	63	74
6Da23	50-75	2-4	Interbedded sst/sh/lst/coal	Shrink/Swell Clay	18+	Interbedded sst/sh/lst/coal	1-100	69	88
6Da24	50-75	2-4	Interbedded sst/sh/lst/coal	Shrink/Swell Clay	6-12	Interbedded sst/sh/lst/coal	1-100	73	100
6Da25	75-100	2-4	Interbedded sst/sh/lst/coal	Sandy Loam	18+	Interbedded sst/sh/lst/coal	1-100	67	82
6Da26	30-50	4-7	Interbedded sst/sh/lst/coal	Sandy Loam	6-12	Interbedded sst/sh/lst/coal	1-100	101	124
6Da27	50-75	2-4	Interbedded sst/sh/lst/coal	Silty Loam	18+	Interbedded sst/sh/lst/coal	1-100	63	73

Setting	Depth to Water(ft)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% slope)	Vadose Zone Media	Hydraulic Conductivity	Rating	Pesticide Rating
6Da28	30-50	4-7	Interbedded sst/sh/lst/coal	Clay Loam	12-18	Interbedded sst/sh/lst/coal	1-100	93	103
6Da29	50-75	2-4	Interbedded sst/sh/lst/coal	Shrink/Swell Clay	2-6	Interbedded sst/sh/lst/coal	1-100	77	112
6Da30	100+	2-4	Interbedded sst/sh/lst/coal	Silty Loam	6-12	Interbedded sst/sh/lst/coal	1-100	57	75
6Da31	30-50	2-4	Interbedded sst/sh/lst/coal	Clay Loam	18+	Interbedded sst/sh/lst/coal	1-100	71	78
6Da32	30-50	2-4	Interbedded sst/sh/lst/coal	Shrink/Swell Clay	6-12	Interbedded sst/sh/lst/coal	1-100	83	110
6Da33	50-75	2-4	Interbedded sst/sh/lst/coal	Thin/Absent Gravel	6-12	Interbedded sst/sh/lst/coal	1-100	79	115
6Da34	50-75	2-4	Interbedded sst/sh/lst/coal	Shrink/Swell Clay	12-18	Interbedded sst/sh/lst/coal	1-100	71	94
6Da35	30-50	2-4	Interbedded sst/sh/lst/coal	Shrink/Swell Clay	2-6	Interbedded sst/sh/lst/coal	1-100	87	122
6Da36	50-75	2-4	Interbedded sst/sh/lst/coal	Thin/Absent Gravel	12-18	Interbedded sst/sh/lst/coal	1-100	77	109
6Da37	30-50	2-4	Interbedded sst/sh/lst/coal	Silty Loam	6-12	Interbedded sst/sh/lst/coal	1-100	77	95
6Da38	30-50	2-4	Interbedded sst/sh/lst/coal	Silty Loam	2-6	Interbedded sst/sh/lst/coal	1-100	81	107
6Da39	30-50	2-4	Interbedded sst/sh/lst/coal	Shrink/Swell Clay	12-18	Interbedded sst/sh/lst/coal	1-100	81	104
6Da40	50-75	2-4	Interbedded sst/sh/lst/coal	Loam	12-18	Interbedded sst/sh/lst/coal	1-100	67	84
6Da41	30-50	2-4	Interbedded sst/sh/lst/coal	Loam	6-12	Interbedded sst/sh/lst/coal	1-100	79	100
6Da42	75-100	2-4	Interbedded sst/sh/lst/coal	Shrink/Swell Clay	18+	Interbedded sst/sh/lst/coal	1-100	64	83
6Da43	75-100	2-4	Interbedded sst/sh/lst/coal	Silty Loam	12-18	Interbedded sst/sh/lst/coal	1-100	60	74
6Da44	50-75	2-4	Interbedded sst/sh/lst/coal	Silty Loam	12-18	Interbedded sst/sh/lst/coal	1-100	65	79
6Da45	50-75	2-4	Interbedded sst/sh/lst/coal	Silty Loam	6-12	Interbedded sst/sh/lst/coal	1-100	67	85
6Da46	30-50	4-7	Interbedded sst/sh/lst/coal	Thin/Absent Gravel	2-6	Interbedded sst/sh/lst/coal	1-100	105	149
6Da47	75-100	2-4	Interbedded sst/sh/lst/coal	Clay Loam	18+	Interbedded sst/sh/lst/coal	1-100	56	63
6Da48	75-100	2-4	Interbedded sst/sh/lst/coal	Shrink/Swell Clay	12-18	Interbedded sst/sh/lst/coal	1-100	66	89
6Da49	30-50	4-7	Interbedded sst/sh/lst/coal	Thin/Absent Gravel	6-12	Interbedded sst/sh/lst/coal	1-100	101	137
6Da50	75-100	2-4	Interbedded sst/sh/lst/coal	Silty Loam	18+	Interbedded sst/sh/lst/coal	1-100	58	68
6Da51	30-50	2-4	Interbedded sst/sh/lst/coal	Shrink/Swell Clay	18+	Interbedded sst/sh/lst/coal	1-100	79	98
6Da52	50-75	2-4	Interbedded sst/sh/lst/coal	Sandy Loam	18+	Interbedded sst/sh/lst/coal	1-100	72	87
6Da53	50-75	2-4	Interbedded sst/sh/lst/coal	Sandy Loam	6-12	Interbedded sst/sh/lst/coal	1-100	76	99
6Da54	30-50	2-4	Interbedded sst/sh/lst/coal	Silty Loam	12-18	Interbedded sst/sh/lst/coal	1-100	75	89
6Da55	30-50	2-4	Interbedded sst/sh/lst/coal	Silty Loam	0-2	Interbedded sst/sh/lst/coal	1-100	82	110
6Da56	15-30	4-7	Interbedded sst/sh/lst/coal	Silty Loam	6-12	Interbedded sst/sh/lst/coal	1-100	99	117

Setting	Depth to Water(ft)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% slope)	Vadose Zone Media	Hydraulic Conductivity	Rating	Pesticide Rating
6Fa1	15-30	4-7	Interbedded sst/sh/lst/coal	Silty Loam	2-6	Silt/clay	1-100	113	137
6Fa2	15-30	4-7	Interbedded sst/sh/lst/coal	Loam	0-2	Interbedded sst/sh/lst/coal	1-100	111	141
6Fa3	15-30	4-7	Interbedded sst/sh/lst/coal	Silty Loam	0-2	Interbedded sst/sh/lst/coal	1-100	109	136
6Fa4	5-15	4-7	Interbedded sst/sh/lst/coal	Silty Loam	0-2	Interbedded sst/sh/lst/coal	1-100	119	146
6Fa5	15-30	4-7	Interbedded sst/sh/lst/coal	Shrink/Swell Clay	0-2	Silt/clay	1-100	113	150
6Fa6	15-30	4-7	Interbedded sst/sh/lst/coal	Clay Loam	0-2	Silt/clay	1-100	107	131
6Fa7	5-15	4-7	Interbedded sst/sh/lst/coal	Silty Loam	0-2	Sand & gravel w/silt & clay	1-100	124	150
6Fb1	30-50	4-7	Interbedded sst/sh/lst/coal	Loam	0-2	Silt/clay	1-100	104	134
6Fb2	30-50	4-7	Interbedded sst/sh/lst/coal	Silty Loam	0-2	Silt/clay	1-100	97	125
6Fb3	15-30	4-7	Interbedded sst/sh/lst/coal	Silty Loam	2-6	Silt/clay	1-100	111	136
6Fb4	15-30	4-7	Interbedded sst/sh/lst/coal	Sandy Loam	2-6	Interbedded sst/sh/lst/coal	1-100	115	146
6Fb5	30-50	4-7	Interbedded sst/sh/lst/coal	Silty Loam	2-6	Interbedded sst/sh/lst/coal	1-100	101	126
6Fb6	15-30	4-7	Interbedded sst/sh/lst/coal	Silty Loam	0-2	Interbedded sst/sh/lst/coal	1-100	109	136
6Fb7	15-30	4-7	Interbedded sst/sh/lst/coal	Loam	0-2	Sand & gravel w/silt & clay	100-300	122	150
6Fb8	30-50	4-7	Interbedded sst/sh/lst/coal	Silty Loam	0-2	Interbedded sst/sh/lst/coal	1-100	99	126
6Fb9	15-30	4-7	Interbedded sst/sh/lst/coal	Shrink/Swell Clay	2-6	Interbedded sst/sh/lst/coal	1-100	109	144
6Fb10	15-30	4-7	Interbedded sst/sh/lst/coal	Silty Loam	2-6	Interbedded sst/sh/lst/coal	1-100	103	129
6Fb11	15-30	4-7	Interbedded sst/sh/lst/coal	Sandy Loam	2-6	Silt/clay	1-100	112	143
6Fb12	15-30	4-7	Interbedded sst/sh/lst/coal	Silty Loam	2-6	Silt/clay	1-100	108	133
6Fb13	15-30	4-7	Interbedded sst/sh/lst/coal	Clay Loam	2-6	Silt/clay	1-100	106	128
6Fb14	30-50	4-7	Interbedded sst/sh/lst/coal	Silty Loam	2-6	Silt/clay	1-100	98	123
6Fb15	5-15	4-7	Interbedded sst/sh/lst/coal	Silty Loam	2-6	Silt/clay	1-100	118	143
6Fb16	15-30	4-7	Interbedded sst/sh/lst/coal	Silty Loam	0-2	Interbedded sst/sh/lst/coal	1-100	112	139
6Fb17	15-30	4-7	Interbedded sst/sh/lst/coal	Shrink/Swell Clay	0-2	Silt/clay	1-100	115	151
7D1	5-15	7-10	Sand & gravel	Silty Loam	0-2	Sand & gravel w/silt & clay	300-700	153	176
7D2	15-30	4-7	Sand & gravel	Silty Loam	0-2	Sand & gravel w/silt & clay	300-700	137	159
7D3	30-50	4-7	Interbedded sst/sh/lst/coal	Silty Loam	0-2	Sand & gravel w/silt & clay	1-100	104	130
7D4	30-50	4-7	Sand & gravel	Clay Loam	0-2	Sand & gravel w/silt & clay	100-300	114	136

Setting	Depth to Water(ft)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% slope)	Vadose Zone Media	Hydraulic Conductivity	Rating	Pesticide Rating
7D5	30-50	4-7	Sand & gravel	Silty Loam	0-2	Sand & gravel w/silt & clay	100-300	116	141
7D6	15-30	4-7	Interbedded sst/sh/lst/coal	Silty Loam	0-2	Sand & gravel w/silt & clay	1-100	114	140
7D7	15-30	4-7	Sand & gravel	Shrink/Swell Clay	0-2	Sand & gravel w/silt & clay	100-300	132	166
7D8	15-30	4-7	Sand & gravel	Silty Loam	0-2	Sand & gravel w/silt & clay	100-300	126	151
7D9	15-30	7-10	Sand & gravel	Silty Loam	0-2	Sand & gravel w/silt & clay	300-700	143	166
7Fa1	5-15	4-7	Interbedded sst/sh/lst/coal	Shrink/Swell Clay	0-2	Sand & gravel w/silt & clay	1-100	130	165
7Fa2	5-15	4-7	Sand & gravel	Silty Loam	0-2	Silt/clay	100-300	136	161
7Fa3	30-50	4-7	Sand & gravel	Silty Loam	6-12	Silt/clay	100-300	106	122
7Fa4	15-30	4-7	Interbedded sst/sh/lst/coal	Shrink/Swell Clay	0-2	Silt/clay	1-100	115	151
7Fa5	15-30	4-7	Interbedded sst/sh/lst/coal	Silty Loam	0-2	Silt/clay	1-100	109	136
7Fa6	15-30	4-7	Interbedded sst/sh/lst/coal	Silty Loam	2-6	Silt/clay	1-100	108	133
7Fa7	30-50	4-7	Interbedded sst/sh/lst/coal	Silty Loam	6-12	Silt/clay	1-100	94	111
7Fa8	15-30	4-7	Interbedded sst/sh/lst/coal	Sandy Loam	2-6	Silt/clay	1-100	112	143
7Fa9	30-50	4-7	Interbedded sst/sh/lst/coal	Silty Loam	2-6	Silt/clay	1-100	98	123
7Fa10	15-30	4-7	Interbedded sst/sh/lst/coal	Silty Loam	0-2	Sand & gravel w/silt & clay	1-100	114	140
7Fa11	15-30	4-7	Sand & gravel	Silty Loam	0-2	Silt/clay	100-300	126	151

Ground Water Pollution Potential of Guernsey County

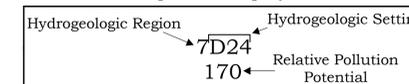
by
Kathy Sprows, 2015
Ohio Department of Natural Resources
Division of Soil and Water Resources



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

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

Description of Map Symbols



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).

Symbol	Index Ranges
Red line	Roads
Blue line	Streams
Blue hatched area	Lakes
Yellow hatched area	Townships
White box	Not Rated
Light blue box	Less Than 79
Light green box	80 - 99
Light blue box	100 - 119
Light green box	120 - 139
Yellow box	140 - 159
Orange box	160 - 179
Red box	180 - 199
Dark red box	Greater Than 200



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

