GROUND WATER POLLUTION POTENTIAL
OF BELMONT COUNTY, OHIO

BY

MICHAEL P. ANGLE AND JOSH JONAK

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ABSTRACT

A ground water pollution potential map of Belmont 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 Belmont County resulted in a map with symbols and colors that illustrate areas of varying ground water contamination vulnerability. Four hydrogeologic settings were identified in Belmont County with computed ground water pollution potential indexes ranging from 56 to 188.

Belmont County lies within the Nonglaciated Central hydrogeologic setting. The buried valley underlying the terraces and floodplains flanking the Ohio River contains sand and gravel outwash which are capable of yielding up to 500 gallons per minute (gpm) from properly designed, large diameter wells. Smaller tributaries contain only thin, fine-grained alluvial/lacustrine deposits commonly yielding less than 10 gpm.

Interbedded dirty sandstones, shales, thin limestones, coals, and claystones of the Pennsylvanian and Permian Systems comprise the aquifer for the majority of Belmont County. These consolidated aquifers are poor aquifers and yields are commonly less than 5 gpm.

The ground water pollution potential mapping program optimizes the use of existing data to rank areas with respect to relative vulnerability to contamination. The ground water pollution potential map of Belmont 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; 3790 of these wells exist in Belmont County.

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

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

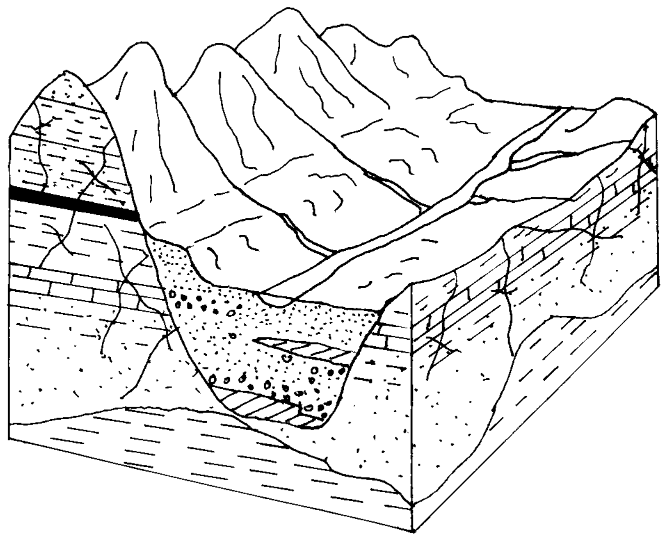
D – Depth to Water
R – Net Recharge
A – Aquifer Media
S – Soil Media
T – Topography
I – Impact of the Vadose Zone Media
C – Conductivity (Hydraulic) of the Aquifer

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.



7D Buried Valley

This setting is characterized by thick deposits of sand and gravel that have been deposited in a former topographic low (usually a pre-glacial river valley) by glacial meltwater. Many of the buried valleys in Belmont County underlie the broad, flat lying floodplains of modern rivers. The boundary between the buried valley and the adjacent bedrock upland is usually prominent. The buried valleys contain substantial thicknesses of permeable sand and gravel that serve as the aquifer. The aquifer is typically in hydraulic connection with the modern rivers. The vadose zone is typically composed of sand and gravel but significant amounts of silt and clay can be found in discrete areas. Silt loams, loams, and sandy loams are the typical soil types for this setting. Depth to water is typically less than 30 feet for areas adjacent to modern rivers, and between 30 to 50 feet for terraces that border the bedrock uplands. Recharge is generally high due to permeable soils and vadose zone materials, shallow depth to water, and the presence of surface streams.

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

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

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

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

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

Weighting and Rating System

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

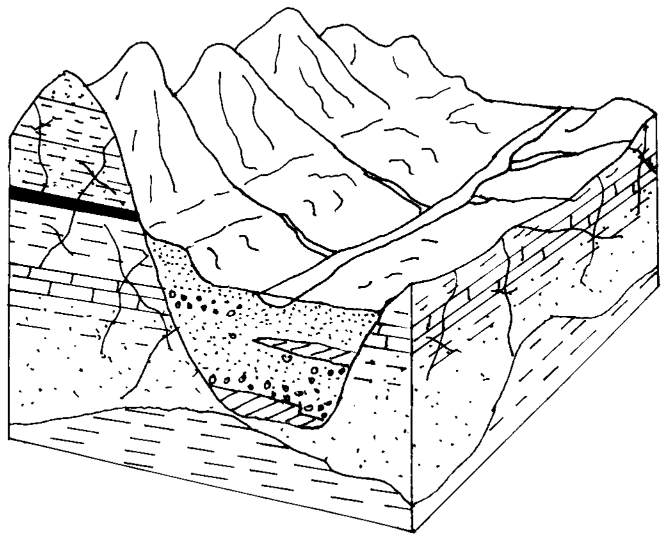
Table 8. Ranges and ratings for hydraulic conductivity

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 Belmont 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 150. 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 Belmont County produces settings with a wide range of vulnerability to ground water contamination. Calculated pollution potential indexes for the 4 settings identified in the county range from 56 to 188.

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 Belmont 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 Belmont 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	8	24
Soil Media	Silt Loam	2	4	8
Topography	2-6%	1	9	9
Impact of Vadose Zone	Silt/Clay	5	4	20
Hydraulic Conductivity	300-700	3	4	12
		DRASTIC	INDEX	150

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 higher the pollution potential index, the greater the susceptibility to contamination. This numeric value determined for one area can be compared to the pollution potential index calculated for another area.

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

7D1 - defines the hydrogeologic region and setting
150 - 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 (**150**) is the calculated pollution potential index for this unique setting. The charts for each setting provide a reference to show how the pollution potential index was derived.

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

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

GENERAL INFORMATION ABOUT BELMONT COUNTY

Demographics

Belmont County occupies approximately 535 square miles in eastern Ohio (Figure 3). Belmont County is bounded to the west by Guernsey County, to the north by Harrison County and Jefferson County, and to the south by Monroe County. The Ohio River bounds Belmont County to the east.

The approximate population of Belmont County, based upon 1998 estimates, is 69,175 (Department of Development, Ohio County Profiles, 1999). Martins Ferry is the largest community and St. Clairsville is the county seat. Most industry and urban land uses are adjacent to the Ohio River. Most modern growth is occurring in the corridor adjacent to Interstate 70. Woodland is a major land use in the county. Agriculture is also an important land use, accounting for approximately 35% of the land area. Strip mining has historically been an important land use in the northern part of the county; underground mining is common throughout the county. More specific information on land usage can be obtained from the Ohio Department of Natural Resources, Division of Real Estate and Land Management (REALM), Resource Analysis Program (formerly OCAP).

Climate

The *Hydrologic Atlas for Ohio* (Harstine, 1991) reports an average annual temperature of approximately 51 degrees Fahrenheit for Belmont County. The average temperatures increase toward the Ohio River. Harstine (1991) shows that precipitation averages 40 inches per year for the county. The mean annual precipitation for Barnesville is 43.15 inches per year based upon a thirty-year (1961-1990) period (Owenby and Ezell, 1992). The mean annual temperature at Barnesville for the same thirty-year period is 48.6 degrees Fahrenheit (Owenby and Ezell, 1992).

Physiography and Topography

Belmont County lies within the Unglaciated Allegheny Plateau section of the Appalachian Plateau Province (Frost, 1931 and Fenneman, 1938). Relatively high relief and rugged topography, featuring narrow ridges, steep slopes, and a high degree of stream dissection characterize the county. Slopes are particularly steep in the eastern part of the county adjacent to the Ohio River. Ridge tops tend to be broader and less steep in the far western margin of the county. Floodplains of the Ohio River are relatively broad and flat lying. The Ohio River is flanked by relatively flat-lying terraces which occur at higher elevations than the floodplains. The highest elevation in the county is 1,397 ft. at Galloway's Knob near St. Clairsville. The lowest elevation is 625 ft, the normal pool elevation of the Ohio River.

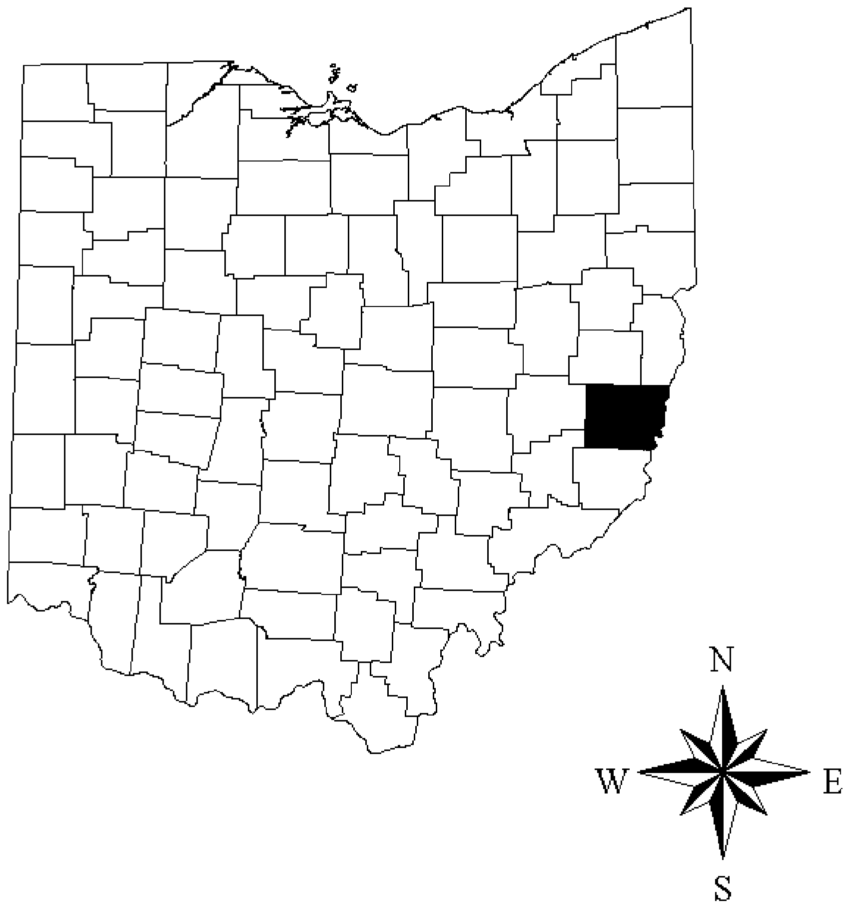


Figure 3. Location of Belmont County, Ohio.

Modern Drainage

A major bedrock ridge, referred to as the Flushing Escarpment by Stout et al. (1943), serves as a major drainage divide to both modern and ancestral drainage systems. In Belmont County, the Flushing Escarpment runs from Flushing to Bethesda to Barnesville. South from Barnesville, the divide roughly follows State Route 147 and State Route 379. East of the escarpment, drainage is toward the Ohio River. The three primary tributaries draining the eastern portion of the county are (from north to south) Wheeling Creek, McMahon Creek, and Captina Creek. North of Barnesville, drainage is towards Stillwater Creek (Piedmont Lake), a tributary of the Tuscarawas River. The extreme southwestern margin of the county is drained by the headwaters of the eastern tributaries of Wills Creek.

Pre- and Inter-Glacial Drainage Changes

Belmont County lies entirely beyond the glacial boundary; however, the drainage patterns of the county were influenced by the multiple glaciations. Belmont County has historically contained the headwater of many tributaries; more marked changes to drainage systems were apparent further downstream, outside of the county.

Prior to glaciation, the Steubenville River (Figure 4) drained Belmont County east of the Flushing Escarpment (Stout et al., 1943). The Steubenville River was a northerly flowing tributary of the Pittsburgh River and roughly followed the course of the present Ohio River. Headwaters of the Steubenville River were to the south in Monroe County. West of the Flushing Escarpment and north of Barnesville, present day Stillwater Creek roughly follows the course of the ancestral Dover River. South of Barnesville, drainage was to the southwest, leading to the headwaters of the Cambridge River. The Cambridge River was part of the Teays River System, the primary drainage system of southern and central Ohio at that time.

As ice advanced through Ohio and northwestern Pennsylvania during the pre-Illinoian (Kansan) glaciation, the Pittsburgh River was blocked by ice. Flow backed-up in the main trunk of the Steubenville River 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 valleys. The new drainage system is referred to as the Deep Stage due to this increased downcutting (Figure 5). The ponded water overtopped and cut a new channel in the divide in Monroe County and drainage reversed, changing to southward flow. The newly created river was referred to as the Pomeroy River (Stout et al., 1943). It was at this time that the ancestral channel of the Ohio River was primarily created. Similarly, ice blocked the flow of the Teays River System. Eventually, new outlets were cut and a new network of tributaries was created. Drainage west of the Flushing Escarpment was toward the Newark River, the major river in south central Ohio at the time.

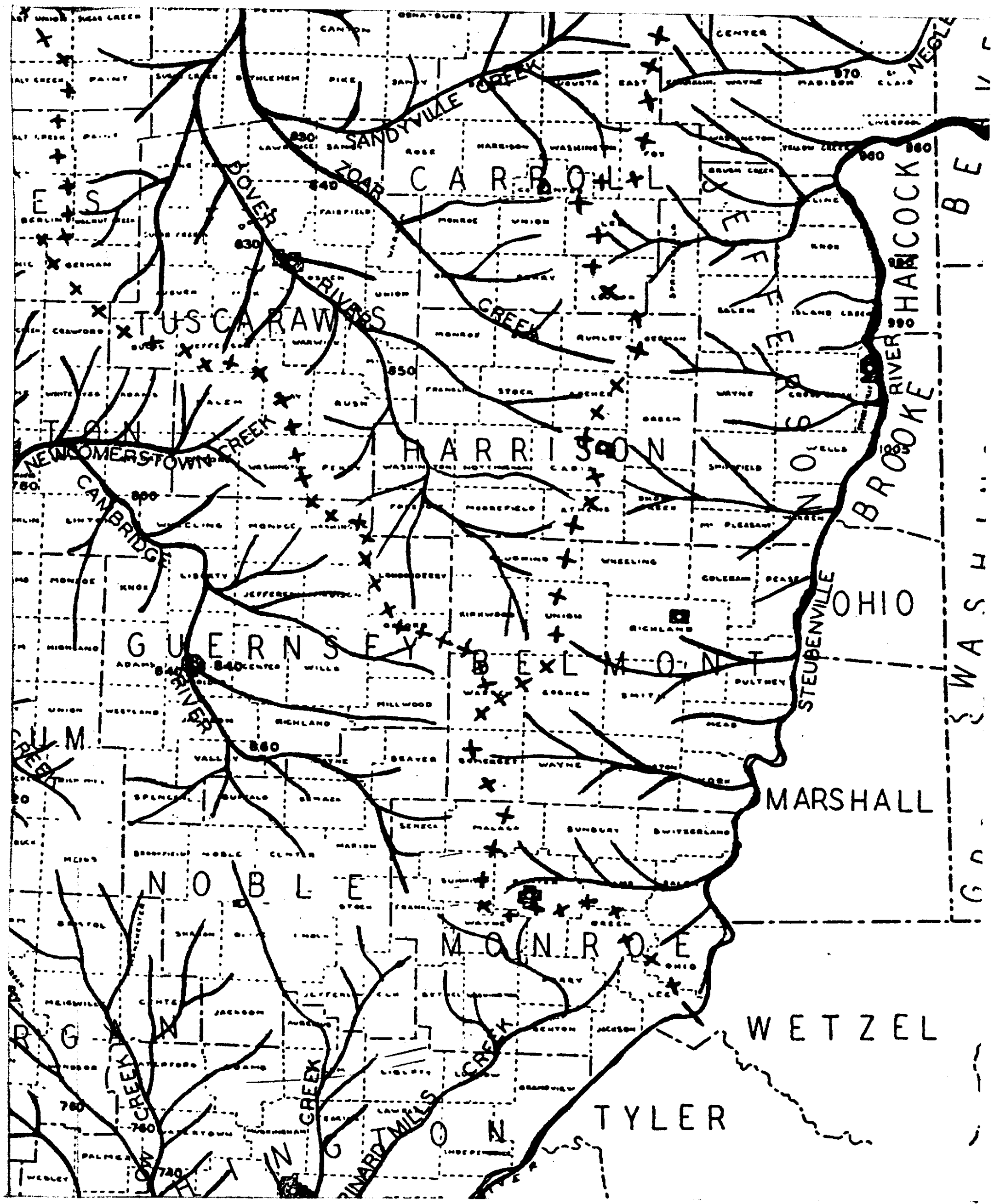


Figure 4. Pre-glacial (Teays Stage) drainage in eastern Ohio. The line of x's indicate the Flushing Escarpment (after Stout et al., 1943).

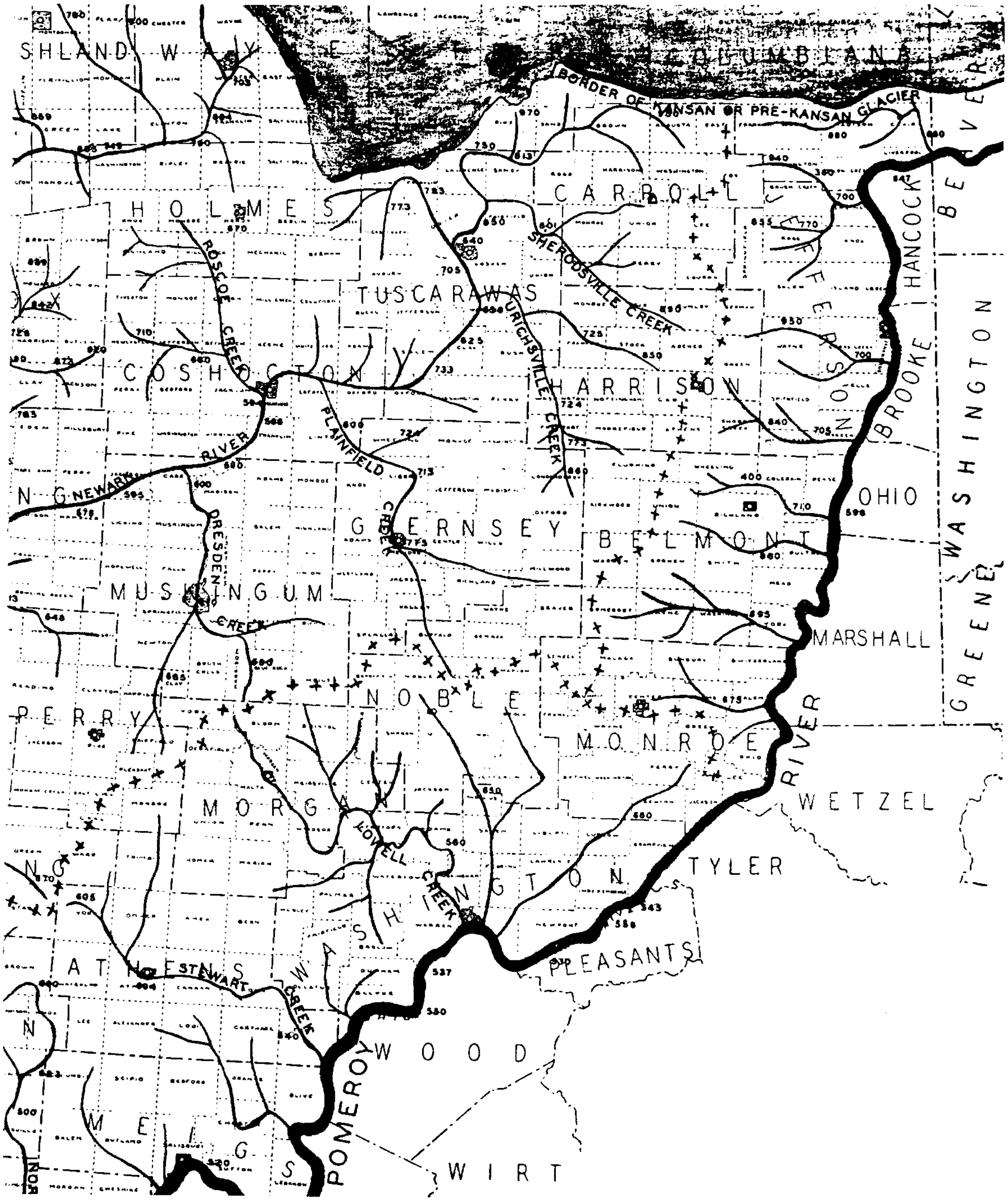


Figure 5. Pre-Illinoian (Deep Stage) drainage in eastern Ohio. The line of x's in Belmont County indicate the Flushing Escarpment (after Stout et al., 1943).

During the time that many of the stream valleys were ponded, abundant sediments were deposited into these streams. The deposits were typically clayey to silty with thin layers of fine-grained sand. Locally, these deposits were referred to as the Minford Silts and were found elsewhere in southeastern Ohio (Stout et al., 1943)

The Illinoian ice advance brought further changes to the drainage systems. The New Martinsville River roughly followed the course of the Pomeroy River, but was not as deeply incised (Figure 6). The present Ohio River very closely follows the New Martinsville River. Drainage to the west of the Flushing Escarpment was still toward the headwaters of the Newark River (Stout et al., 1943).

The massive volumes of meltwater produced during the Wisconsinan (most recent) ice advance deposited thick, coarse outwash, creating the terraces flanking the Ohio River. Deposits along the margin of the Ohio River contain a variety of coarse outwash, silty alluvial (floodplain) and finer lacustrine (lake) sediments which were deposited over time. Coarse sand and gravel outwash were interbedded with finer-grained alluvial deposits in many areas of the Ohio River valley. Ancestral stream channels filled with glacial/alluvial sediments are referred to as buried valleys. Small tributaries of the Ohio River also contain a variety of interbedded fine and coarse sediments.

Bedrock Geology

Bedrock exposed at the surface in Belmont County belongs to the Pennsylvanian and Permian Systems. Table 9 summarizes the bedrock stratigraphy found in Belmont County. The ODNR, Division of Geological Survey, has Open-File Reconnaissance Bedrock Geological Maps done on a 1:24,000 USGS topographic map base available for the entire county. The oldest rocks exposed in Belmont County are part of the Conemaugh Group and are typically found near the base of the deeper stream cuts in the western and northeastern part of the county. Rocks of the Conemaugh Group 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 in western Belmont County as well as near the base of some of the deeper-incised valleys leading into the Ohio River. These rocks include interbedded dirty sandstones, shales, minor limestones, and some important coal beds, particularly in the northern part of the county. Coal beds associated with the Monongahela Group are mined underground further south and east in the county where these units are limited to the subsurface.

Rocks belonging to the Permian System are prevalent in much of eastern and southern Belmont County. These rocks include dirty sandstones, fine shales, and soft mudstones. The mudstones and shales tend to be calcareous and soft. Limestones are commonly freshwater and are dense and fine-grained. Sandstones are micaceous and have a high iron content. Typically, the rocks have a reddish to grayish look and may have been deposited under somewhat arid conditions (Collins, 1979). These rocks tend to be somewhat less resistant to erosion and tend to form broader, less steep ridge tops.

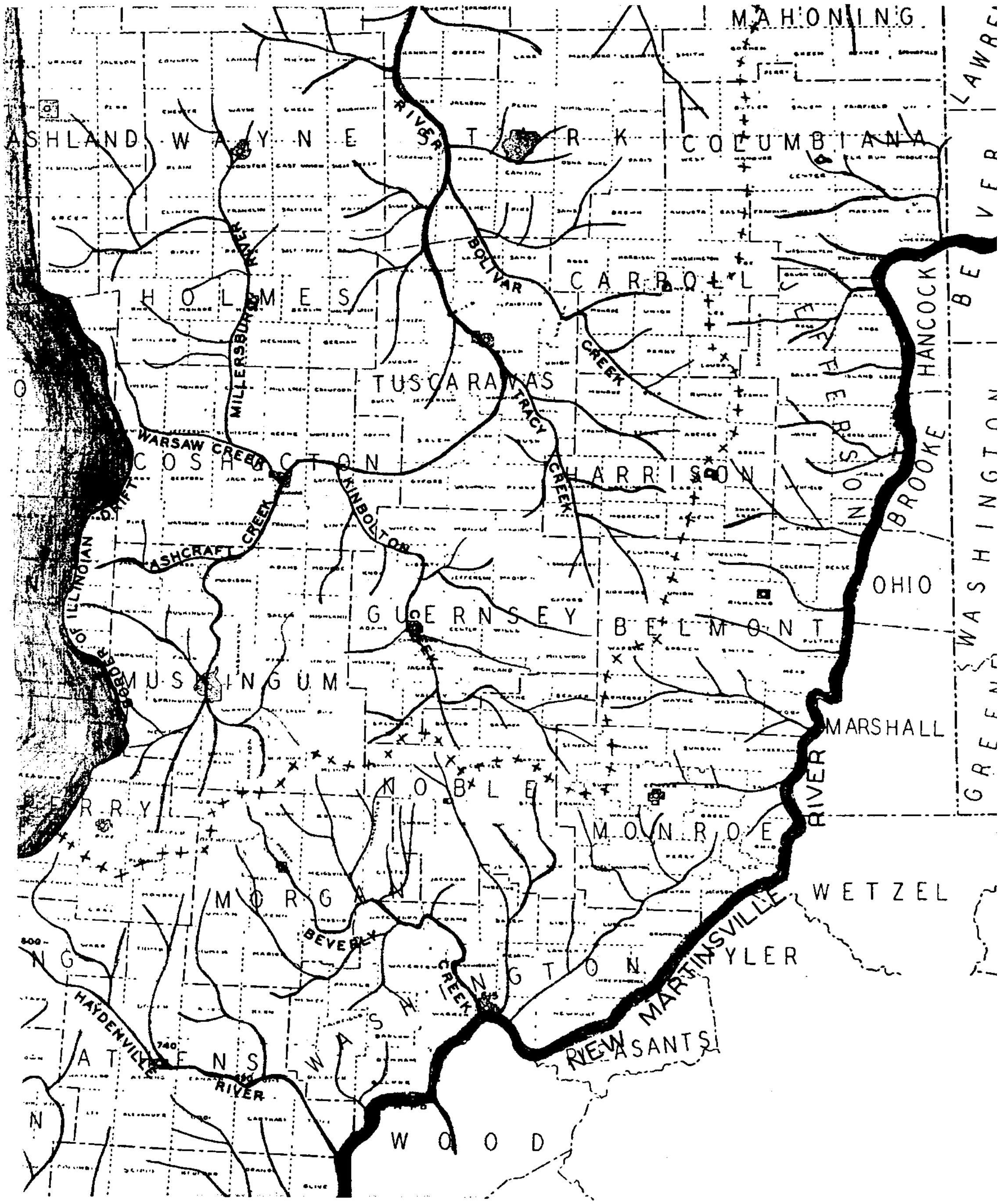


Figure 6. Post-Illinoian drainage in eastern Ohio. The line of x's in Belmont County indicate the Flushing Escarpment (after Stout et al., 1943).

Table 9. Bedrock Stratigraphy of Belmont County

System	Group/Formation (Symbol)	Lithologic Description
Permian	Dunkard (Pd)	Thin bedded to massive variable colored shales, siltstones, mudstones, dirty sandstones with minor amounts of coal and limestone. Widespread across most of the ridge tops in Belmont County. Poor aquifer with yields less than 5 gpm.
Pennsylvanian	Pennsylvanian Undifferentiated (Pu) Monongahela Conemaugh	Darkish brown shales, siltstones and dirty sandstones with minor amounts of clay, coal, limestone and flint. Found in western Belmont County and in most valley bottoms. Poor aquifer with yields commonly less than 5 gpm.

Weedman (1990) provides an excellent account of the complex depositional environments, which created the rocks of the Pennsylvanian System. These highly transitional environments included both terrestrial ("land-based") and marine derived sediments. The terrestrial environment was dominated by large river systems featuring broad alluvial plains upland from coastal areas. Stream channels and point bar deposits were the source of sandstones and conglomerates. Shales and siltstones were derived from fine-grained floodplain deposits. Freshwater limestones were deposited in shallow, rapidly evaporating lakes and ponds found on the alluvial plain. The terrestrial environment was highly transitional with the 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 Conemaugh 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 Belmont County is obtained from both unconsolidated (glacial-alluvial) and consolidated (bedrock) aquifers. Glacial aquifers are primarily limited to the main trunk of the terraces and floodplain flanking the Ohio River. Unconsolidated alluvial and lacustrine sediments are also found near the mouth of some of the larger tributaries of the

Ohio River including Wheeling Creek, McMahon Creek, and especially Captina Creek. Other tributaries in the county contain deposits that are either too thin or fine-grained to constitute sustainable aquifers.

Yields up to 500 gpm are obtainable from the coarse, well-sorted sand and gravel outwash deposits associated with the terraces flanking the Ohio River (Walker, 1991 and ODNR, Division 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 high sustainable yields capable from these larger diameter wells. Smaller diameter wells should be suitable for serving domestic/farm needs within this aquifer. Areas of high terraces along the extreme margin of the valley tend to contain deposits containing less coarse gravel and predominantly fine-grained sand. Yields in these areas range from 25 to 100 gpm. The deposits located in the lower parts of Captina Creek, McMahon Creek, and Wheeling Creek contain thin sand and gravel interbedded with thicker sequences of finer-grained lacustrine and alluvial deposits. Yields fall in the 5 to 10 gpm range. Other major tributaries typically are too thin, dirty, and fine-grained and constitute a very marginal aquifer (Walker, 1991 and ODNR, Division Of Water Open File, Glacial State Aquifer Map). These fine-grained deposits more likely help provide extra recharge to the underlying bedrock.

Yields from the consolidated, bedrock aquifers throughout the county tend to be meager. Yields typically tend to be especially poor along ridge tops. Walker (1991) and the ODNR, Division Of Water, Open File, Bedrock State Aquifer Map shows the bedrock yielding less than 5 gpm for the entire county.

The yield in any particular area is dependent upon the number and type of formations drilled. Wells drilled into 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 can 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 ridgetops. 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 Belmont 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 Belmont County. Delineations of mined areas were made using information from the *Soil Survey of Belmont County* (Rubel et al., 1981), abandoned underground mine maps (ODNR, Division of Geological Survey, open file maps), and the Belmont 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
	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 3790 water well log records are on file for Belmont County. Data from roughly 2,500 water well log records were analyzed and plotted on U.S.G.S. 7-1/2 minute topographic maps during the course of the project. Static water levels and information as to the depths at which water was encountered were taken from these records. The *Ground Water Resources of Belmont County* (Walker, 1991) provided generalized depth to water information throughout the county. 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 the areas overlying floodplains immediately adjacent to the Ohio River and major tributaries. 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) were applied to very high, isolated ridge tops. These ridge tops are usually capped by thick sequences of fine-grained Pennsylvanian or Permian 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. Mapping in adjoining Harrison County (Angle and Walker, 2002) proved useful as a guideline for evaluating recharge.

Values of 7 to 10 inches per year (8) were assigned to terraces and floodplains flanking the Ohio River. 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. A recharge value of 0 to 2 inches per year (1) was applied to very steep, high ridges where the soils are thin to absent and run-off is very high on the bare bedrock slopes.

Aquifer Media

Information on aquifer media was obtained from the reports of Stout et al. (1943), and Walker (1991). Mapping in adjoining Harrison County (Angle and Walker, 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 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 associated with terraces and floodplains flanking the Ohio River. An aquifer rating of (7) was used for some thinner sand and gravel deposits associated with terraces along the margins of the Ohio River. These terraces tend to contain less coarse gravel and more fine-grained sand. An aquifer rating of (6) was used for predominantly fine-grained sediments in Wheeling Creek and McMahon Creek and a rating of (5) was utilized for the aquifer below Captina Creek.

An aquifer rating of (3) was assigned to the Pennsylvanian and Permian bedrock in Belmont County.

Soils

Soils were mapped using the data obtained from the *Soil Survey of Belmont County* (Rubel et al., 1981). 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 Belmont 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 Belmont 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 sandy loams (6) in outwash-rich terraces along the Ohio River. Loam soils (5) were also selected for coarser residual bedrock ridges. Shrink-swell clays (7) were rated for upland areas having very clayey shale and mudstone bedrock residuum. Shrink-swell clays (7) were rated for fine-grained lacustrine slackwater sediments in 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. Clay loam (3) soils were evaluated for fine-grained bedrock residuum.

Table 12. Soils of Belmont County, Ohio

Soil Name	Parent Material Or Setting	DRASTIC Rating	Soil Media
Allegheny	Alluvial terraces	4	Silt loam
Ashton	Alluvial terraces and fans	4	Silt loam
Barkcamp	Strip mine	NA	Not rated
Bethesda	Strip mine	NA	Not rated
Brookside	Clayey interbedded rock	7	Shrink-swell
Chagrin	Alluvium, floodplain	4	Silt loam
Chili	Outwash, coarse alluvium	6	Sandy loam
Culleoka	Interbedded sandstone, shale and siltstone	10	Thin or absent
Dekalb	Sandstone outcrops	10	Thin or absent
Duncannon	Loess on terraces, slopes	4	Silt loam
Elba	Fine-grained calcareous bedrock	7	Shrink-swell
Elkinsville	Alluvium, floodplain	4	Silt loam
Fairport	Strip mine	NA	Not rated
Fitchville	Alluvium, floodplains	4	Silt loam
Hartshorn	Coarse alluvium, narrow valleys	6	Sandy loam
Lowell	Fine interbedded shale and siltstone	3	Clay loam
Lowell-Westmoreland	Fine interbedded shale and siltstone	3	Clay loam
Morristown	Strip mine	NA	Not rated
Newark	Alluvium, floodplain	4	Silt loam
Newark variant	Thin alluvium over sandstone	6	Sandy loam
Nolin	Alluvium, floodplain	4	Silt loam
Otwell	Old alluvial terrace	4	Silt loam
Richland	Colluvium from interbedded rocks	5	Loam
Wellston	Interbedded sandstone and siltstone	4	Silt loam
Westmore	Fine-grained calcareous bedrock	7	Shrink-swell
Westmoreland	Interbedded sandstone, shale, and siltstone	3	Clay loam
Westmoreland-Upshur	Clayey shale, and siltstone	7	Shrink-swell
Zanesville	Fine siltstone and shale	3	Clay loam

Topography

Topography, or percent slope, was evaluated using U.S.G.S. 7-1/2 minute quadrangle maps and the *Soil Survey of Belmont County* (Rubel et al., 1981). 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) were 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) and Walker (1991). Mapping in adjoining Harrison County (Angle and Walker, 2002) 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 Belmont County* (Rubel et al., 1981), 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 (6) and (7) for sand and gravel interbedded with silt and clay layers for the terraces and floodplains flanking the Ohio River. These ratings depend upon the proportion of coarse, well-sorted outwash to the finer-grained alluvial and lacustrine deposits. Silt and clay with a rating of (5) was selected for vadose zone media within 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 and Permian 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 Belmont County was found lacking. Information from Walker (1991), the ODNR, Division of Water, Glacial State Aquifer Map and Bedrock State Aquifer Map, and water well log records on file at the ODNR, Division of

Water, were the primary sources of information. Hydraulic conductivity values utilized in adjoining Harrison County (Angle and Walker, 2002) proved to be a useful guideline. Textbook tables (Freeze and Cherry, 1979; 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. For example, 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) and 1,000-2,000 gpd/ft^2 (8) were selected. These high values were limited to the clean outwash deposits associated with terraces and floodplains flanking the Ohio River. For sand and gravel deposits along the margins of the Ohio River, hydraulic conductivities of 700-1,000 gpd/ft^2 (6) and 300-700 gpd/ft^2 (4) were utilized. In these deposits, thin sand and gravel lenses were interbedded with finer-grained materials

All of the bedrock aquifers were assigned hydraulic conductivity values of 1-100 gpd/ft^2 (1) due to the overall low permeability of these interbedded sedimentary rocks.

APPENDIX B

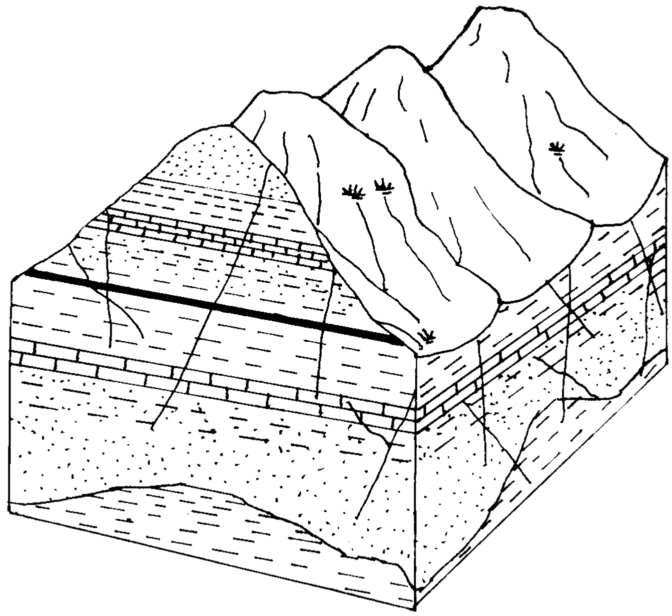
DESCRIPTION OF HYDROGEOLOGIC SETTINGS AND CHARTS

Ground water pollution potential mapping in Belmont County resulted in the identification of 4 hydrogeologic settings within the Nonglaciated Central Region. The list of these settings, the range of pollution potential indexes, and the number of index calculations for each setting are provided in Table 13. Computed pollution potential indexes for Belmont County range from 56 to 188.

Table 13. Hydrogeologic settings mapped in Belmont County, Ohio

Hydrogeologic Settings	Range of GWPP Indexes	Number of Index Calculations
6Da - Alternating Sandstone, Limestone, and Shale – Thin Regolith	56-93	32
6Fa - River Alluvium Without Overbank Deposits	96-124	11
7D – Buried Valley	140-188	9
7Fa - Glacial Lakes and Slackwater Terraces	137-142	3

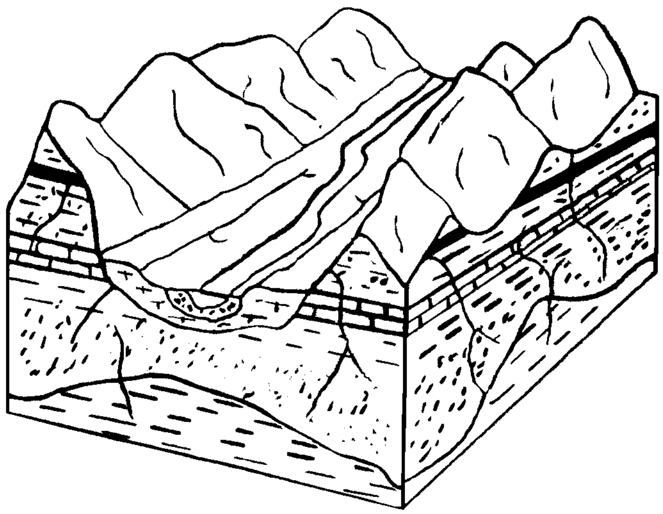
The following information provides a description of each hydrogeologic setting identified in the county, a block diagram illustrating the characteristics of the setting, and a listing of the charts for each unique combination of pollution potential indexes calculated for each setting. The charts provide 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 Belmont 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 Permian Systems. Multiple aquifers are typically present. Depth to water is generally deep; shallower perched zones may overlie low permeability shales, limestones, and clays. Soils are generally thin to absent on steeper slopes. On gentler slopes, soils vary with the bedrock lithology. Small supplies of ground water are obtained from intersecting bedding planes or vertical fractures. Ground water yields average less than 5 gpm. Recharge is limited due to the steep slopes, deep aquifers, and layers of impermeable bedrock.

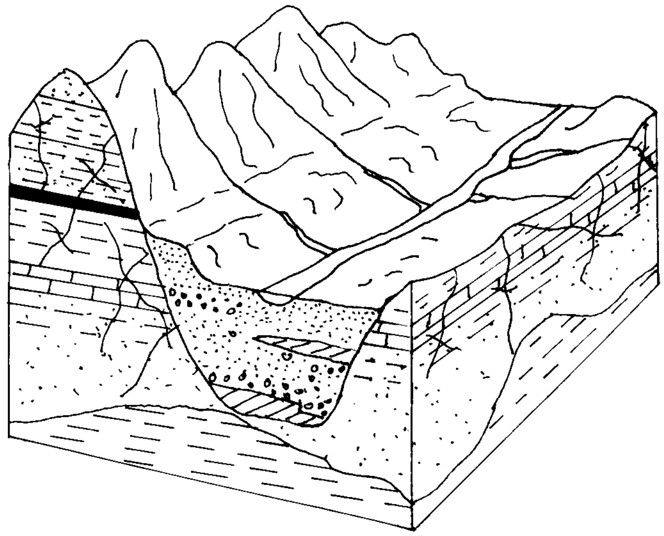
GWPP index values for the hydrogeologic setting of Alternating Sandstone, Limestone, and Shale – Thin Regolith range from 56 to 93 with the total number of GWPP index calculations equaling 32.



6Fa River Alluvium with Overbank Deposits

This hydrogeologic setting is limited to small tributary valleys in the uplands of Belmont 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 somewhat thinner. Areas in this setting are similar to the adjacent uplands, which belong to the 6Da Alternating Sandstone, Limestone, and 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 and Permian Systems. In most areas, the alluvium is in direct connection with the underlying bedrock aquifers. Ground water yields average less than 5 gpm. Recharge is moderate due to the relatively shallow depth to water, flatter topography, and the relatively low permeability of the bedrock. Recharge is higher than the surrounding uplands.

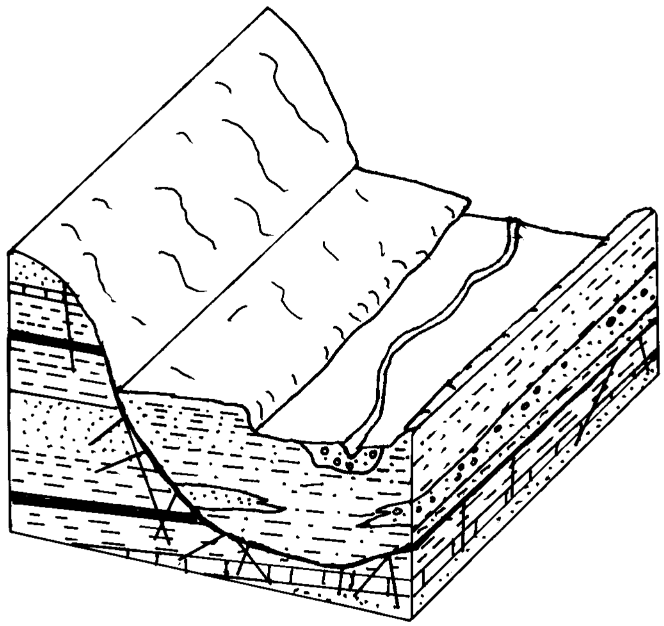
GWPP index values for the hydrogeologic setting of River Alluvium with Overbank Deposits range from 96 to 124 with the total number of GWPP index calculations equaling 11.



7D Buried Valleys

This hydrogeologic setting is limited to the terraces and floodplains adjacent to the Ohio River. The setting is easy to distinguish from the surrounding uplands. The broad, flat-lying floodplains and gently sloping terraces characterize the setting. Depth to water is typically less than 30 feet. Aquifers are composed of variable thicknesses of sand and gravel interbedded with finer-grained alluvium and lacustrine deposits. The Ohio River may be in direct hydraulic connection with the underlying and adjacent aquifers. Yields up to 500 gpm have been reported for some of the coarser, thicker, more continuous sand and gravel units. Soils are typically sandy loams derived from outwash. 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 140 to 188 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 slackwater 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 drift than the somewhat similar 6Fa River Alluvium with Overbank Deposits. The setting is bordered by steep bedrock uplands. The drift is not as thick or as coarse as in adjacent 7D Buried Valley settings. The aquifer consists of thin sand and gravel lenses interbedded with finer lacustrine and alluvial deposits. If sand and gravel is not encountered, wells are completed in the underlying interbedded sedimentary rock. Depth to water is commonly shallow due to the presence of streams found within this setting. 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.

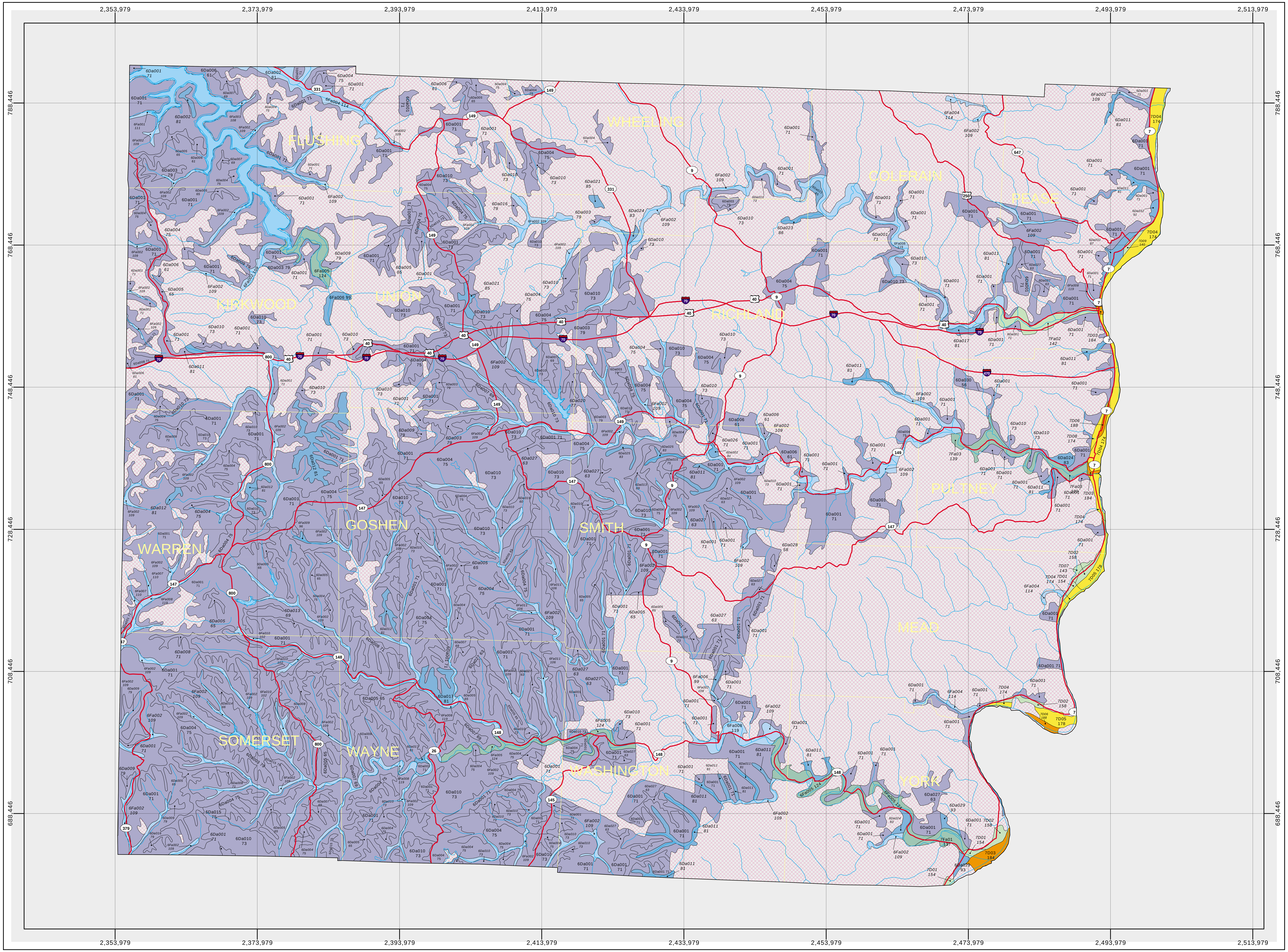
GWPP index values for the hydrogeologic setting of Glacial Lakes and Slackwater Terraces range from 137 to 142 with the total number of GWPP index calculations equaling 3.

Table 14. Hydrogeologic Settings, DRASTIC Factors, and Ratings

Setting	Depth To Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% Slope)	Vadose Zone Media	Hydraulic Conductivity	Rating
6Da001	30-50	2-4	interbedded ss/sh/ls/cl/coal	Clay Loam	18+	interbedded ss/sh/ls/cl/coal	1-100	71
6Da002	30-50	2-4	interbedded ss/sh/ls/cl/coal	Silty Loam	2-6	interbedded ss/sh/ls/cl/coal	1-100	81
6Da003	30-50	2-4	interbedded ss/sh/ls/cl/coal	Clay Loam	2-6	interbedded ss/sh/ls/cl/coal	1-100	79
6Da004	30-50	2-4	interbedded ss/sh/ls/cl/coal	Clay Loam	6-12	interbedded ss/sh/ls/cl/coal	1-100	75
6Da005	50-75	2-4	interbedded ss/sh/ls/cl/coal	Clay Loam	6-12	interbedded ss/sh/ls/cl/coal	1-100	65
6Da006	50-75	2-4	interbedded ss/sh/ls/cl/coal	Clay Loam	18+	interbedded ss/sh/ls/cl/coal	1-100	61
6Da007	50-75	2-4	interbedded ss/sh/ls/cl/coal	Clay Loam	2-6	interbedded ss/sh/ls/cl/coal	1-100	69
6Da008	50-75	0-2	interbedded ss/sh/ls/cl/coal	Thin/Absent Gravel	6-12	interbedded ss/sh/ls/cl/coal	1-100	71
6Da009	30-50	2-4	interbedded ss/sh/ls/cl/coal	Shrink/Swell Clay	18+	interbedded ss/sh/ls/cl/coal	1-100	79
6Da010	30-50	2-4	interbedded ss/sh/ls/cl/coal	Clay Loam	12-18	interbedded ss/sh/ls/cl/coal	1-100	73
6Da011	15-30	2-4	interbedded ss/sh/ls/cl/coal	Clay Loam	18+	interbedded ss/sh/ls/cl/coal	1-100	81
6Da012	30-50	0-2	interbedded ss/sh/ls/cl/coal	Thin/Absent Gravel	6-12	interbedded ss/sh/ls/cl/coal	1-100	81
6Da013	50-75	0-2	interbedded ss/sh/ls/cl/coal	Thin/Absent Gravel	12-18	interbedded ss/sh/ls/cl/coal	1-100	69
6Da014	75-100	0-2	interbedded ss/sh/ls/cl/coal	Thin/Absent Gravel	6-12	interbedded ss/sh/ls/cl/coal	1-100	66
6Da015	50-75	0-2	interbedded ss/sh/ls/cl/coal	Thin/Absent Gravel	2-6	interbedded ss/sh/ls/cl/coal	1-100	75
6Da016	30-50	0-2	interbedded ss/sh/ls/cl/coal	Thin/Absent Gravel	12-18	interbedded ss/sh/ls/cl/coal	1-100	79
6Da017	30-50	2-4	interbedded ss/sh/ls/cl/coal	Shrink/Swell Clay	12-18	interbedded ss/sh/ls/cl/coal	1-100	81
6Da019	75-100	2-4	interbedded ss/sh/ls/cl/coal	Clay Loam	6-12	interbedded ss/sh/ls/cl/coal	1-100	60
6Da020	50-75	2-4	interbedded ss/sh/ls/cl/coal	Shrink/Swell Clay	2-6	interbedded ss/sh/ls/cl/coal	1-100	77
6Da021	30-50	0-2	interbedded ss/sh/ls/cl/coal	Thin/Absent Gravel	2-6	interbedded ss/sh/ls/cl/coal	1-100	85
6Da023	15-30	2-4	interbedded ss/sh/ls/cl/coal	Clay Loam	18+	interbedded ss/sh/ls/cl/coal	1-100	86
6Da024	30-50	2-4	interbedded ss/sh/ls/cl/coal	Shrink/Swell Clay	6-12	interbedded ss/sh/ls/cl/coal	1-100	83
6Da025	15-30	2-4	interbedded ss/sh/ls/cl/coal	Clay Loam	12-18	interbedded ss/sh/ls/cl/coal	1-100	83
6Da026	50-75	2-4	interbedded ss/sh/ls/cl/coal	Silty Loam	2-6	interbedded ss/sh/ls/cl/coal	1-100	71

Setting	Depth To Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% Slope)	Vadose Zone Media	Hydraulic Conductivity	Rating
6Da027	50-75	2-4	interbedded ss/sh/ls/cl/coal	Clay Loam	12-18	interbedded ss/sh/ls/cl/coal	1-100	63
6Da028	75-100	2-4	interbedded ss/sh/ls/cl/coal	Clay Loam	12-18	interbedded ss/sh/ls/cl/coal	1-100	58
6Da029	15-30	2-4	interbedded ss/sh/ls/cl/coal	Shrink/Swell Clay	6-12	interbedded ss/sh/ls/cl/coal	1-100	93
6Da030	75-100	2-4	interbedded ss/sh/ls/cl/coal	Clay Loam	18+	interbedded ss/sh/ls/cl/coal	1-100	56
6Da031	30-50	2-4	interbedded ss/sh/ls/cl/coal	Shrink/Swell Clay	2-6	interbedded ss/sh/ls/cl/coal	1-100	87
6Da032	15-30	2-4	interbedded ss/sh/ls/cl/coal	Shrink/Swell Clay	12-18	interbedded ss/sh/ls/cl/coal	1-100	91
6Fa01	15-30	4-7	interbedded ss/sh/ls/cl/coal	Loam	0-2	interbedded ss/sh/ls/cl/coal	1-100	111
6Fa02	15-30	4-7	interbedded ss/sh/ls/cl/coal	Silty Loam	0-2	interbedded ss/sh/ls/cl/coal	1-100	109
6Fa03	15-30	4-7	interbedded ss/sh/ls/cl/coal	Silty Loam	2-6	interbedded ss/sh/ls/cl/coal	1-100	108
6Fa04	15-30	4-7	interbedded ss/sh/ls/cl/coal	Silty Loam	0-2	silt/clay	1-100	114
6Fa05	5-15	4-7	interbedded ss/sh/ls/cl/coal	Silty Loam	0-2	silt/clay	1-100	124
6Fa06	30-50	4-7	interbedded ss/sh/ls/cl/coal	Silty Loam	0-2	interbedded ss/sh/ls/cl/coal	1-100	99
6Fa07	15-30	4-7	interbedded ss/sh/ls/cl/coal	Loam	2-6	interbedded ss/sh/ls/cl/coal	1-100	110
6Fa08	5-15	4-7	interbedded ss/sh/ls/cl/coal	Silty Loam	0-2	interbedded ss/sh/ls/cl/coal	1-100	119
6Fa09	30-50	4-7	interbedded ss/sh/ls/cl/coal	Clay Loam	2-6	interbedded ss/sh/ls/cl/coal	1-100	96
6Fa10	15-30	4-7	interbedded ss/sh/ls/cl/coal	Clay Loam	6-12	interbedded ss/sh/ls/cl/coal	1-100	102
6Fa11	15-30	4-7	interbedded ss/sh/ls/cl/coal	Clay Loam	2-6	interbedded ss/sh/ls/cl/coal	1-100	106
7D01	15-30	7-10	sand + gravel	Silty Loam	0-2	sd + gvl w/ silt + clay	700-1000	154
7D02	15-30	7-10	sand + gravel	Sandy Loam	0-2	sd + gvl w/ silt + clay	700-1000	158
7D03	5-15	7-10	sand + gravel	Silty Loam	0-2	sd + gvl w/ silt + clay	2000+	184
7D04	15-30	7-10	sand + gravel	Silty Loam	0-2	sd + gvl w/ silt + clay	2000+	174
7D05	15-30	7-10	sand + gravel	Sandy Loam	0-2	sd + gvl w/ silt + clay	2000+	178
7D06	5-15	7-10	sand + gravel	Sandy Loam	0-2	sd + gvl w/ silt + clay	2000+	188
7D07	15-30	7-10	sand + gravel	Silty Loam	0-2	sd + gvl w/ silt + clay	300-700	143
7D08	5-15	7-10	sand + gravel	Shrink/Swell Clay	0-2	silt/clay	1000-2000	174

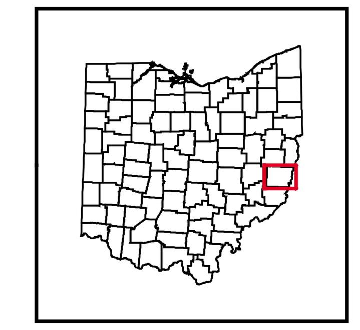
Setting	Depth To Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% Slope)	Vadose Zone Media	Hydraulic Conductivity	Rating
7D09	30-50	4-7	sand + gravel	Sandy Loam	0-2	sd + gvl w/ silt + clay	700-1000	140
7Fa01	15-30	4-7	sand + gravel	Silty Loam	0-2	sd + gvl w/ silt + clay	300-700	137
7Fa02	5-15	4-7	sand + gravel	Silty Loam	0-2	sd + gvl w/ silt + clay	300-700	142
7Fa03	5-15	4-7	sand + gravel	Silty Loam	0-2	sd + gvl w/ silt + clay	300-700	139



Ground Water Pollution Potential of Belmont County

by

Michael P. Angle and Josh Jonak
Ohio Department of Natural Resources



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

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

Description of Map Symbols

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

Legend

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

Symbols	Index Ranges
Roads	Not Rated
Streams	Less Than 79
Lakes	80 - 99
Townships	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
2002