# GROUND WATER POLLUTION POTENTIAL OF CRAWFORD COUNTY, OHIO

**BY**

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## ABSTRACT

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

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

Ground water pollution potential analysis in Crawford County resulted in a map with symbols and colors, which illustrate areas of varying ground water pollution potential indexes ranging from 88 to 157.

Crawford County lies entirely within the Glaciated Central hydrogeologic setting. Limestones and dolomites of the Silurian and Devonian Systems compose the aquifer in the western quarter of the county. Yields in the uppermost carbonate aquifers range from 5 to 25 gallons per minute (gpm) to 25 to 100 gpm. Yields over 100 gpm are possible from larger diameter wells drilled deeper into the limestone. Shales of the Devonian System and Mississippian System comprise the aquifer in the central and eastern portions of the county. Yields from these rocks are poor, typically yielding less than 5 gpm. Interbedded sandstones, shales, and siltstones of the Mississippian System in the southeastern portion of the county have yields in the 5 to 25 gpm range.

Sand and gravel lenses interbedded in the glacial till locally serve as aquifers in much of central and eastern Crawford County. Sand and gravel lenses are most predominant within end moraines. In some areas, the sand and gravel lenses may lie directly on top of the shale bedrock and serve as the aquifer or provide additional recharge to the underlying bedrock. Yields for these sand and gravel lenses range from 5 to 25 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 Crawford County has been prepared to assist planners, managers, and local officials in evaluating the potential for contamination from various sources of pollution. This information can be used to help direct resources and land use activities to appropriate area, or to assist in protection, monitoring, and clean-up efforts.

TABLE OF CONTENTS

LIST OF FIGURES

Number Page

LIST OF TABLES

Number Page

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| | |
|---|---|
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# INTRODUCTION

The need for protection and management of ground water resources in Ohio has been clearly recognized. About 42 percent of Ohio citizens rely on ground water for drinking and household use from both municipal and private wells. Industry and agriculture also utilize significant quantities of ground water for processing and irrigation. In Ohio, approximately 750,000 rural households depend on private wells; 5600 of these wells exist in Crawford County.

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

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

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

## APPLICATIONS OF POLLUTION POTENTIAL MAPS

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

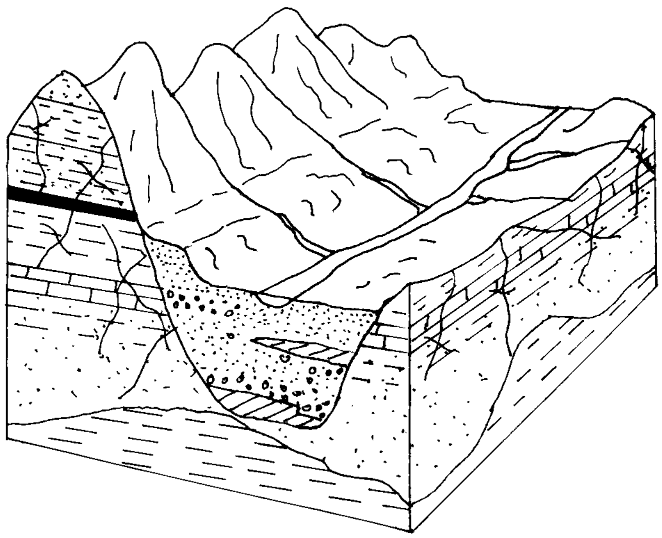
C – Conductivity (Hydraulic) of the Aquifer

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 hydrogeologic setting is found in the southeastern corner of Crawford County. The buried valley lacks surficial expression and is not overlain by a modern stream. The setting is characterized by overlying flat ground moraine and rolling, hummocky end moraines. The aquifer consists of relatively thin sand and gravel lenses interbedded with glacial till within the moraine. These sand and gravel deposits differ as to lateral extent and thickness and are found at varying depths. Yields range from the 5 to 25 gpm. The vadose zone is composed of loamy to clayey glacial till. The till may be fractured or jointed, particularly in areas where it is predominantly thin and weathered. Depth to water is variable and depends primarily upon how deep the underlying sand and gravel lenses are. Soils are commonly clay loams. Recharge is variable with lower recharge where ground moraine overlies the buried valley and higher recharge where end moraines overlie the buried valley.

GWPP index values for the hydrogeologic setting of Buried Valley range from 112 to 137, with the total number of GWPP index calculations equaling 7.

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 | |

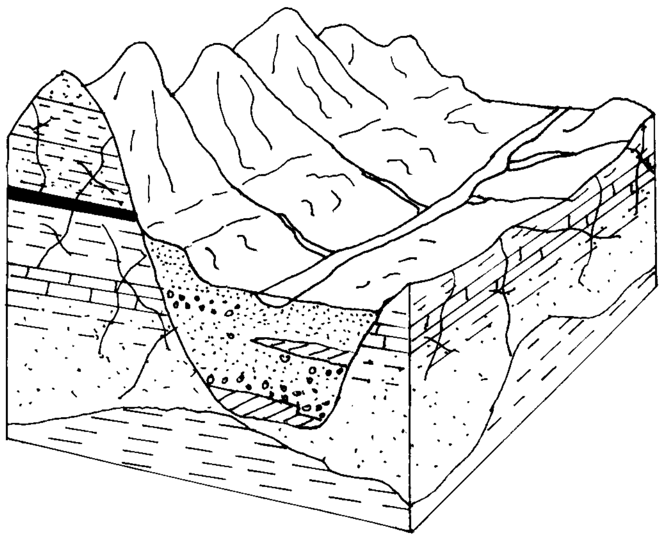
Table 8. Ranges and ratings for hydraulic conductivity

| 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 Crawford 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 125. 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 Crawford County produces settings with a wide range of vulnerability to ground water contamination. Calculated pollution potential indexes for the nine settings identified in the county range from 88 to 157.

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 Crawford 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 Crawford County is included with this report.



| SETTING 7D1 | | GENERAL | | |
| --- | --- | --- | --- | --- |
| **FEATURE** | **RANGE** | **WEIGHT** | **RATING** | **NUMBER** |
| Depth to Water | 15-30 | 5 | 7 | 35 |
| Net Recharge | 4-7 | 4 | 6 | 24 |
| Aquifer Media | Sand & Gravel | 3 | 6 | 18 |
| Soil Media | Clay Loam | 2 | 3 | 6 |
| Topography | 0-2% | 1 | 10 | 10 |
| Impact of Vadose Zone | Till | 5 | 4 | 20 |
| Hydraulic Conductivity | 300-700 | 3 | 4 | 12 |
| | | DRASTIC | INDEX | 125 |

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
125 - 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 (**125**) 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 CRAWFORD COUNTY

## Demographics

Crawford County occupies approximately 404 square miles in north central Ohio (Figure 3). Crawford County is bounded to the north by Seneca County and Huron County, to the east by Richland County, to the south by Morrow County and Marion County, and to the west by Wyandot County.

The approximate population of Crawford County, based upon year 2000 census estimates, is 46,966 (Department of Development, Ohio County Profiles, 2002). Bucyrus is the largest community and the county seat. Agriculture accounts for roughly 90 percent of the land usage in Crawford County. Row crops are the primary agricultural land usage. Woodlands, industry, and residential are the other major land uses in 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 50 degrees Fahrenheit for Crawford County. The average temperatures decrease slightly towards the east. Harstine (1991) shows that precipitation approximately averages 36 inches per year for the county, with precipitation decreasing towards the west. The mean annual precipitation for Bucyrus is 37.9 inches per year based upon a twenty-year (1961-1980) period (Owenby and Ezell, 1992). The mean annual temperature at Bucyrus for the same twenty-year period is 48.5 degrees Fahrenheit (Owenby and Ezell, 1992).

## Physiography and Topography

Crawford County lies within the Central Till Plains Lowland Province (Frost, 1931; Fenneman, 1938, and Bier, 1956). Brockman (1998) and Schiefer (2002) determined that the majority of Crawford County belongs in the Central Ohio Clayey Till Plain and that the southeastern corner of the County is part of the Galion Glaciated Low Plateau. Crawford County is characterized by flat ground moraine and intermorainal lakes separated by linear, hummocky end moraines.

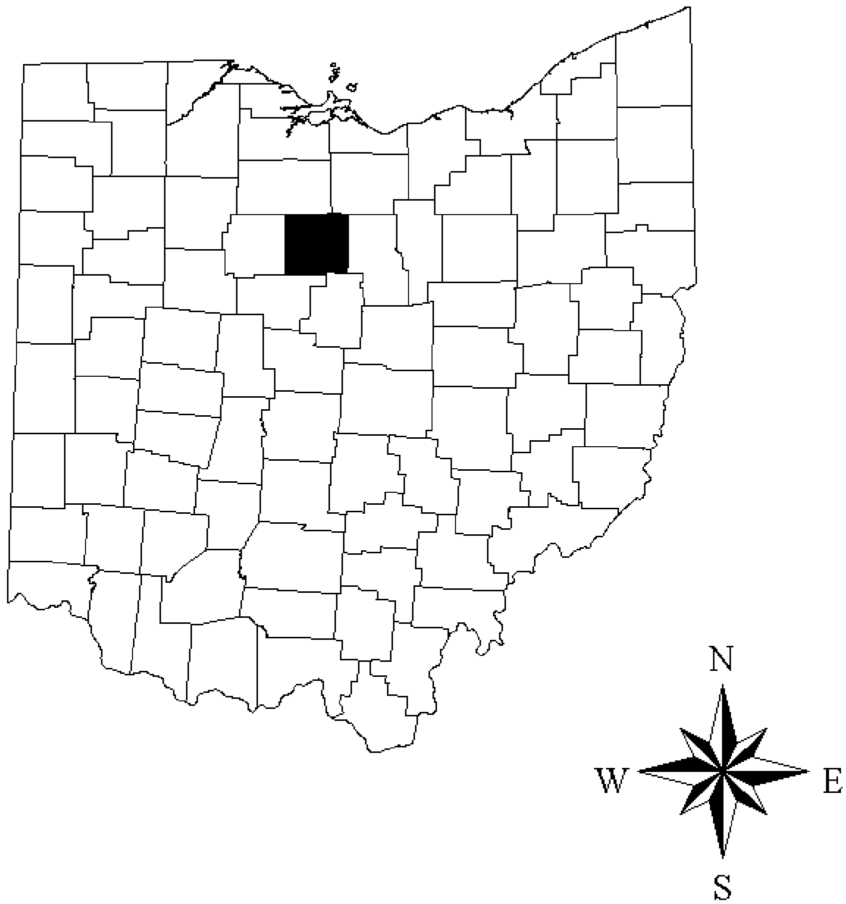



Figure 3.  Location map of Crawford County, Ohio.

## Modern Drainage

The divide between the headwaters of the Lake Erie Basin and the Ohio River Basin extends across parts of southern and eastern Crawford County. The West Branch of the Huron River drains the northeastern corner of the county. The southern margin of the county is drained by the headwaters of the Scioto River and the Olentangy River and its tributary, Mud Run. The Sandusky River and its tributaries drain the majority of the county. The headwaters of the Sandusky River flow westward from the town of Crestline. Important tributaries of the Sandusky River that have their headwaters in Crawford County include Broken Sword Creek, Sycamore Creek, and Honey Creek. These tributaries all flow westward.

## Pre- and Inter-Glacial Drainage Changes

Little information is available on the pre-glacial drainage of Crawford County. Stout et al. (1943) suggested that during pre-glacial (Teays Stage Drainage) times that Crawford County contained the headwaters of the Tiffin River. The Tiffin River was an ancestor of and had a course similar to that of the modern Sandusky River. The drainage patterns of Crawford County largely reflect the terrain resulting from the final, Wisconsinan glacial advances.

## Glacial Geology

During the Pleistocene Epoch (2 million to 10,000 years before present (Y.B.P.)) several episodes of ice advance occurred in northwestern Ohio. Older ice advances that predate the most recent (Brunhes) magnetic reversal (about 730,000 Y.B.P.) are now commonly referred to as pre-Illinoian (formerly Kansan). Goldthwait et al., (1961) and Pavey et al., (1999) report that the last advance, the Late Wisconsinan Ice Sheet, deposited the surficial till in Crawford County. Evidence for the earlier glaciations is lacking or obscured.

Gregory (1956) and Totten (1987) discuss the glacial deposits of Crawford County at length. In a recent study, Russell (2002) reevaluated the lacustrine deposits related to the intermorainal lakes found in the county. His study was the basis for the delineation of the 7Fc-Intermorainal Lake Deposits hydrogeologic setting. The *Soil Survey of Crawford County* (Steiger et al., 1979) was used to make the delineations between the lakebeds and ground moraine. The exceptional flatness of these features and characteristics of poor drainage also proved useful in delineating the intermorainal lakes. The majority of the glacial deposits in Crawford County fall into three main types: (glacial) till, lacustrine deposits, and ice-contact sand and gravel (kames, eskers) deposits. Drift is an older term that collectively refers to the entire sequence glacial deposits. Overall, drift is thinner in areas of ground moraine and thickens somewhat in end moraines. The drift overall thickens toward the northeast and southeast corners (ODNR, Division of Geological Survey, Open File Bedrock Topography and ODNR, Division of Water, Glacial State Aquifer Map).

Till is an unsorted, non-stratified (non-bedded), mixture of sand, gravel, silt, and clay deposited directly by the ice sheet. There are two main types or facies of glacial till. Lodgement till is "plastered-down" or "bulldozed" at the base of an actively moving ice sheet. Lodgement till tends to be relatively dense and compacted and pebbles typically are angular, broken, and have a preferred direction or orientation. "Hardpan" and "boulder-clay" are two common terms used for lodgement till. Ablation or "melt-out" till occurs as the ice sheet melts or stagnates away. Debris bands are laid down or stacked as the ice between the bands melts. Ablation till tends to be less dense, less compacted, and slightly coarser as meltwater commonly washes away some of the fine silt and clay. There is evidence that some of the tills were deposited in a water-rich environment in Crawford County. These types of tills would be deposited when a relatively thin ice sheet would alternately float and ground depending on the water level of the lake and thickness of the ice sheet. Such tills may more closely resemble lacustrine deposits.

Till has relatively low inherent permeability. Permeability in till is in part dependent upon the primary porosity of the till which reflects how fine-textured the particular till is. Vertical permeability in till is controlled largely by factors influencing the secondary porosity such as fractures (joints), worm burrows, root channels, sand seams, etc. (Brockman and Szabo, 2000 and Haefner, 2000). Of importance in the end moraines of Crawford County is the high proportion of sand and gravel units interbedded in the till. These units may overlap enough ("stack") to help aid in permeability. Fractures may also interconnect the sand and gravel lenses.

At the land surface, till accounts for two primary landforms: ground moraine and end moraine. Ground moraine (till plain) is relatively flat to gently rolling. End moraines are ridge-like, with terrain that is steeper and more rolling or hummocky. End moraines commonly serve as a local drainage divide due to their ridge-like nature. The Fort Wayne Moraine, Wabash End Moraine, and St. Johns End Moraine all coalesce together in the central part of Crawford County, northeast of Bucyrus. The Broadway End Moraine trends northward to the center of the county, passing just west of Galion. The Powell End Moraine is located in the extreme southeast corner of the county. The New Washington End Moraine occupies the northeast corner of the county.

Kames and eskers are ice contact features. They are composed of masses of generally poorly sorted sand and gravel with minor till, deposited in depressions, holes, tunnels, or other cavities in the ice. As the surrounding ice melts, a mound of sediment remains behind. Typically, these deposits may collapse or flow as the surrounding ice melts. These deposits may display high angle, distorted or tilted beds, faults, and folds. The best examples of ice contact deposits are found along the eastern margin of the Broadway Moraine in the vicinity of the villages of Leesville and Middletown.

Crawford County contains abundant kettles. Melting blocks of ice formed these small, circular depressional features. As the ice block melted, it left behind a hole or low area surrounded by either till or outwash. Kettles may also reflect lows or "swales" in an end moraine which are flanked by highs or "swells". Kettles commonly contain standing water. The water may reflect the local water table conditions or may collect and perch local runoff. Kettles also contain peat and muck. Peat and muck are organic-rich deposits associated with low-lying depression areas, bogs, kettles, and swamps. Muck is dense, fine silt with a high content of organics and a dark black color. Peat is typically brownish and contains pieces of plant fibers, decaying wood, and mosses. The two deposits commonly occur together, the *Soil Survey of Crawford County* (Steiger et al., 1979) show numerous organic deposits that have filled kettles. The kettles are typically underlain by either highly permeable sand and gravel outwash or by low permeability lacustrine silt and clay or till.

Lacustrine deposits are composed of silty to clayey material. These lakes are referred to as intermorainal lakes as they occupy low areas of ground moraine between end moraines. The lakes tend to become somewhat finer-grained near the center of the deposit or lake (Gregory, 1956, House, 1985, and Russell, 2002). Lacustrine deposits tend to be laminated (or varved) and contain various proportions of silts and clays. Thin layers of fine sand may reflect storm or flood events. Permeability is preferentially horizontal due to the laminations and water-laid nature of these sediments. The inherent vertical permeability is slow; however, secondary porosity features such as fractures, joints, root channels, etc. help increase the vertical permeability. Thin layers of sand typically occupy the margins of the lakes. These sands may reflect minor deltas that started to prograde into the lake, or they may mark the rough beginnings of a shoreline.

The lakes were created during the recession of the ice sheets. Meltwater was trapped between the receding ice sheet and end moraines. In some areas, meltwater may have been trapped between two end moraines forming a lake. Additional ponding may have resulted from northerly-flowing, run-off fed streams that were blocked by the ice sheets. Run-off in general helped to fill these ponds. Eventually, some of these ponds may have overflowed their margins and began to cut an outlet. House (1985) and Russell (2002) theorized that as one lake overflowed, it would progressively cause the next lower elevation lake to overflow. Alternatively, the headwaters of emerging streams may have cutback and created an outlet for the lakes. As the modern drainage system slowly developed, streams downcut through the series of end moraines, draining the lakes over time. Swampy bog and kettle areas replaced many of the lakes. Many of these features persist to today or were recently drained for agriculture.

## Bedrock Geology

Bedrock underlying the surface of Crawford County belongs to the Silurian, Devonian, and Mississippian Systems. Carbonate (limestone and dolomite) bedrock underlies the western quarter of Crawford County; the central portion is underlain by shale and interbedded sandstones and shales underlie the eastern third. Table 9 summarizes the bedrock stratigraphy found in Crawford County. The ODNR, Division of Geological Survey, has Open-File

Reconnaissance Bedrock Geological Maps done on a 1:24,000 scale USGS topographic map base available for the entire county. The ODNR, Division of Water, has Open File Bedrock State Aquifer mapping available for the county also.

Silurian and Devonian carbonates are found in the western quarter of Crawford County. The oldest unit typically encountered by water wells is the Silurian Lockport Group. The Lockport Group rocks were associated with tidal reefs deposited in warm, high-energy shallow seas. Overlying the Lockport Group are rocks of the Silurian Tymochtee and Greenfield Formations, which were also deposited in warm, shallow seas. The uppermost Silurian unit is the Salina Undifferentiated Group that consists of dolomites, fine-grained limestones, and some minor evaporite deposits such as gypsum. These rocks were deposited in warm, shallow tidal areas. The uppermost carbonate units are the fossiliferous Columbus and Delaware Limestones. These rocks were deposited in warm, high-energy seas and reef areas.

Devonian age Ohio and Olentangy Shale (ODNR, Division of Water, Bedrock State Aquifer Map, 2000) underlies much of central Crawford County. These thick, dark brown to black fissile shales were deposited in deep oceans that had limited circulation of fresher waters and sediments. These shales are rich in organic matter, pyrite, and locally, natural gas.

Mississippian age rocks show a shift to deltaic, fluvial, and shoreline deposits. The oldest unit is the Bedford Shale found across east central Crawford County. It is comprised of very fine-grained silt and clay particles deposited in the outer (distal) margins of a delta. The Berea Sandstone overlies the Bedford Shale in eastern Crawford County. It consists of fine-grained, tightly cemented sand particles that consisted of river sediments that were re-deposited along adjacent shorelines. The Sunbury Shale is found along the eastern margin of Crawford County and is similar to the Devonian Ohio Shale. This unit may indicate the localized return to a low circulation environment. The Mississippian Cuyahoga Formation is found in the southeastern corner of the county. This unit is composed of interbedded fine-grained sandstones, shales, and siltstones and represents deltaic to fluvial sediments deposited in a rapidly fluctuating, shoreline environment.

## Ground Water Resources

Ground water in Crawford County is obtained from both unconsolidated (glacial-alluvial) and consolidated (bedrock) aquifers. Glacial aquifers are primarily associated with thin lenses of sand and gravel interbedded with till. Sand and gravel aquifers are commonly associated with end moraine deposits. Sand and gravel deposits are more commonly utilized in areas with underlying shale bedrock. The carbonate aquifer is an important regional aquifer for most of northwestern Ohio and occupies the western quarter of Crawford County. Interbedded Sandstone+Shale aquifers in the eastern portion of the county provide ample yields for domestic and farm needs. Yields from shales are typically low and are marginal for supplying even domestic needs. Completed water wells typically penetrate multiple bedrock units.

Table 9. Bedrock stratigraphy of Crawford County

| System | Group/Formation (Symbol) | Lithologic Description |
|---|---|---|
| Mississippian | Cuyahoga Group (Mcg) | Gray to brown shale with interbedded fine-grained sandstone and siltstone. Local thickness usually <100 feet. Moderate aquifer, typically yielding 5-25 gpm. |
| | Sunbury Shale (Ms) | Black to brownish-black, carbonaceous, thin-bedded, and fissile shale. Poor aquifer, typically yielding <5 gpm. |
| | Berea Sandstone (Mb) | Light bluish-gray very fine-grained sandstone. Bedding is variable, grains are tightly cemented. Local thickness <100 feet. Very poor aquifer, typically yielding <5 gpm. |
| | Bedford Shale (Mbd) | Gray to brown, soft, massive, fine-grained, clay-rich shale. Local thickness <100 feet. Very poor aquifer, typically yielding <5 gpm. |
| Devonian | Ohio and Olentangy Shales (Dohol) | Black to brownish-black, thin-bedded, organic, pyritic, carbonaceous shale. Thickness >100 feet in eastern part of the county, and thins westward. Poor aquifer, typically yielding <5 gpm. |
| | Delaware and Columbus Limestones (Ddc) | The Delaware is a gray to brown thin-bedded to massive, argillaceous, carbonaceous limestone. The Columbus is a gray to brown, fossiliferous, massive-bedded limestone and dolomite. Karst features are common in the Columbus. In much of Crawford County, these units are >100 feet in thickness. Yields are usually 5-100 gpm. Thickness and yields for these formations decreases toward the western edge of the county. The water quality deteriorates in areas where these units are overlain by thick Ohio and Olentangy Shale. |
| Silurian | Undifferentiated Salina Dolomite (Sus) | Gray to brown, thin-bedded, argillaceous dolomite. Thin evaporite zones common. Thickness >100 feet. Yields may exceed 100 gpm when fractures or solution features are encountered. |
| | Tymochtee and Greenfield Dolomites (Stg) | Thin- to massive-bedded, olive-gray to yellowish-brown. The Tymochtee contains shale partings. The Greenfield has a laminated dolomite lithology. Combined thickness exceeds 100 feet. Yields can be >100 gpm, especially in the Tymochtee. |
| | Lockport Dolomite (Sl) | White to medium gray, medium to massive-bedded dolomite. Commonly contains cavernous solution zones. Thickness >100 feet. Yields can exceed 100 gpm, especially in cavernous or solution zones. |

Yields exceeding 100 gpm (ODNR, Div. Of Water, Open File, Bedrock State Aquifer Map, 2000, ODNR, Div. Of Water, 1970, and Schmidt, 1981) are available from deep, larger diameter wells drilled into the Silurian Salina Undifferentiated Group, the Tymochtee and Greenfield Dolomites, and the Lockport Dolomite. These formations extend across the western quarter of the county at depth. Yields for the Devonian Columbus and Delaware Limestones vary from 25-100 gpm to 5-25 gpm (ODNR, Div. of Water, Open File, Bedrock State Aquifer Map, 2000, ODNR, Div. Of Water, 1970, and Schmidt, 1981). The trend of increasing yields in deeper wells drilled into the carbonates is a generalization. The amount of fracturing, solution, and vuggy (porous) zones has great local importance. Deeper wells are also more likely to contain highly mineralized water and have objectionable water quality. Carbonate aquifers that underlie the thick sequence of shales in west central Crawford County may not be desirable (ODNR, Div. of Water, Open File, Bedrock State Aquifer Map, 2000). Water underlying the shale tends to be very high in sulfur, hydrogen sulfide, and iron.

The Devonian Ohio and Olentangy Shales in central Crawford County are a poor source of ground water. Yields are typically under 5 gpm (ODNR, Div. of Water, Open File, Bedrock State Aquifer Map, 2000 and Schmidt, 1981). Typically, the uppermost 10 to 15 feet of the shale is weathered and broken and provides the most water. Wells drilled deeper into the shale provide increased well storage, but typically little additional water. The water quality becomes more objectionable with depth. Yields from the Mississippian Bedford Shale in east central Crawford County and the Sunbury Shale in eastern Crawford County are also typically less than 5 gpm (ODNR, Div. of Water, Open File, Bedrock State Aquifer Map, 2000 and Schmidt, 1981). Yields from the Mississippian Berea Sandstone in eastern Crawford County range from 5 to 25 gpm (ODNR, Div. of Water, Open File, Bedrock State Aquifer Map, 2000 and Schmidt, 1981). Yields obtained from the interbedded fine-grained sandstones, shales, and siltstones of the Cuyahoga Formation in the southeastern corner of the county also yield 5 to 25 gpm (ODNR, Div. of Water, Open File, Bedrock State Aquifer Map, 2000 and Schmidt, 1981).

Yields from sand and gravel lenses interbedded with the fine-grained till averages 5 to 25 gpm (ODNR, Div. of Water, Glacial State Aquifer Map, 2000 and Schmidt, 1981). The sand and gravel may also directly overlie the bedrock and yield 5 to 25 gpm. The drillers may penetrate the bedrock directly below the sand and gravel. In such cases the bedrock acts as a "screen" to help filter fines out of the gravel. Sand and gravel lenses are most commonly associated with the thicker drift of end moraines. Yields obtained from thin sand and gravel lenses interbedded in till in a buried valley in southeastern Crawford County also yield 5 to 25 gpm (ODNR, Div. of Water, Open File, Bedrock State Aquifer Map, 2000 and Schmidt, 1981). Schmidt (1981) reported that the glacial deposits were primarily fine-grained sands and lacked gravel in the northeastern part of the county. It is important to note that sand and gravel wells are much more commonly utilized in central Crawford County as the underlying shale is a much poorer aquifer than the carbonates to the west or sandstones to the southeast.

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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 5,600 water well log records are on file for Crawford County. Data from roughly 2, 500 located 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 water was encountered at were taken from these records. The *Ground Water Resources of Crawford County* (Schmidt, 1981) provided generalized depth to water information throughout the county. Depth to water trends mapped in adjoining Seneca County (Smith and Voytek, 1994) and Huron County (Powers et al., 1994) were used as a guideline. Topographic and geomorphic trends were utilized in areas where other sources of data were lacking.

Depths to water of 0 to 5 (10) were used for some limited floodplain areas adjacent to the headwaters of some minor streams. Depths of 5 to 15 feet (9) were selected for most of the alluvial settings, ground moraine, intermorainal lakes and areas with shale bedrock aquifers. Depths of 15 to 30 feet (7) were used for alluvial settings in the western part of the county and for some of the more subdued end moraines. Depths of 30 to 50 feet (5) were utilized for the 7Ac-Till over Limestone in the western quarter of the county and for some of the higher relief end moraines in the central portion of the county. Depths to water of 50 to 75 feet (3) and 75 to 100 feet (2) were utilized for some limited deeper limestone aquifers in the northwestern portion of the county.

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) and Dumouchelle and Schiefer (2002) proved to be helpful. Recharge ratings from Seneca County (Smith and Voytek, 1994) and Huron County (Powers et al., 1994) were used as a guideline.

Values of 4 to 7 inches per year (6) were used for areas with moderate recharge. These areas include all of the alluvial settings in the county and all of the end moraines. Values of 2 to 4 inches per year (3) were utilized for most areas associated with ground moraine, intermorainal lakes and for deeper bedrock aquifers.

Aquifer Media

Information on evaluating aquifer media was obtained primarily from the *Ground Water Resources of Crawford County* (Schmidt, 1981). Open File Bedrock Reconnaissance Maps and Open File Bedrock Topography Maps, based upon U.S.G.S. 7-1/2 minute topographic maps from the ODNR, Division of Geological Survey proved helpful. Aquifer ratings from neighboring Seneca County (Smith and Voytek, 1994) and Huron County (Powers et al., 1994) were used as a guideline. 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.

All of the bedrock and most of the interbedded lenses of sand and gravel are semi-confined or leaky; however for the purposes of DRASTIC, they have been evaluated as being unconfined (Aller et al., 1987). Massive limestone was evaluated as the aquifer in the 7Ac-Glacial Till over Limestone and in adjacent settings with carbonate aquifers. A rating of (7) was applied to the Silurian and Devonian limestones that comprise the aquifer in western Crawford County. An aquifer rating of (9) was applied to limestone in the northwestern corner of the county. These rocks were evaluated as having more solution features and higher secondary porosity in neighboring Seneca County (Smith and Voytek, 1994), perhaps due to the thinner cover of protective drift in most of this county.

An aquifer rating of (5) for sandstone and interbedded Sandstone+Shale was used for an area in Vernon Township in which the wells had higher yields and lower drawdowns than in the remainder of the county. An aquifer rating of (4) was used for interbedded Sandstone+Shale aquifers elsewhere in eastern Crawford County. An aquifer rating of (3) was utilized for shale aquifers in most of central Crawford County. Black shale with an aquifer rating of (2) was selected for some exceptionally poor aquifers in east central Crawford County.

For sand and gravel aquifers a rating of (7) was given to somewhat higher-yielding deposits in Cranberry Township. Sand and gravel aquifers elsewhere were assigned a rating of (6) or (5) depending upon how clean, coarse and thick the deposits were.

Soils

Soils were mapped using the data obtained from the *Soil Survey of Crawford County* (Steiger et al., 1979). 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. Special emphasis is placed upon determining the most restrictive layer. The soils of Crawford County showed a high degree of variability. This is a reflection of the parent material. Table 10 is a list of the soils, parent materials, setting, and corresponding DRASTIC values for Crawford County.

Table 10. Crawford County soils

| Soil Name | Parent Material/ Setting | DRASTIC Rating | Soil Media |
|---|---|---|---|
| Alexandria | Clayey till | 3 | Clay loam |
| Bennington | Clayey till | 3 | Clay loam |
| Blount | Loamy till | 3 | Clay loam |
| Bogart | Outwash, kame | 6 | Sandy loam |
| Bono | Lacustrine | 3 | Clay loam |
| Cardington | Clayey till | 3 | Clay loam |
| Carlisle | Kettle, bogs | 8 | Peat |
| Chili | Outwash, kame | 6 | Sandy loam |
| Colwood | Deltaic, shoreline | 6 | Sandy loam |
| Condit | Clayey till | 3 | Clay loam |
| Del Rey | Lacustrine | 3 | Clay loam |
| Elliot | Clayey till | 3 | Clay loam |
| Fitchville | Deltaic, lacustrine | 4 | Silt loam |
| Gallman | Outwash bordering end moraine | 6 | Sandy loam |
| Glynwood | Loamy till | 3 | Clay loam |
| Hennepin | Clayey till | 3 | Clay loam |
| Jimtown | Outwash, kame | 6 | Sandy loam |
| Kibbie | Outwash, kame | 6 | Sandy loam |
| Lenawee | Lacustrine | 3 | Clay loam |
| Lobdell | Alluvium | 4 | Silt loam |
| Luray | Lacustrine | 3 | Clay loam |
| Lykens | Lacustrine | 3 | Clay loam |
| Marengo | Clayey till | 3 | Clay loam |
| Medway | Alluvium | 4 | Silt loam |
| Mitiwanga | Sandstone residuum | 10 | Thin or absent |
| Muskego | Kettle, bogs | 8 | Peat |
| Olentangy | Depressions, lacustrine | 2 | Muck |
| Olmsted | Outwash, alluvium, deltaic | 6 | Sandy loam |
| Pewamo | Clayey till | 3 | Clay loam |
| Sebring | Lacustrine | 3 | Clay loam |
| Shoals | Alluvium | 4 | Silt loam |
| Sloan | Alluvium | 4 | Silt loam |
| Tiro | Lacustrine | 3 | Clay loam |
| Tuscola | Lacustrine | 3 | Clay loam |
| Woodsworth | Loamy till | 3 | Clay loam |
| Wallkill | Kettles | 2 | Muck |
| Wilmer | Outwash bordering end moraine | 6 | Sandy loam |

Soils were considered to be sandy loam (6) for a limited number of exposures of outwash/ kame sand and gravel. Loam soils (5) and silt loams (4) were designated for alluvial and floodplain deposits. Clay loam (3) soils were evaluated for the majority of the county including till overlying ground moraine and end moraine and lacustrine deposits associated with the intermorainal lakes. For the purposes of determining the hydrogeologic setting, clay loam soils were differentiated as to whether they overly ground moraine versus intermorainal lakes. Muck (2) was evaluated for soils associated with some minor kettles.

## Topography

Topography, or percent slope, was evaluated using U.S.G.S. 7-1/2 minute quadrangle maps and the Soil Survey of Crawford County (Steiger et al., 1979). Slopes of 0 to 2 percent (10) were selected for almost all of the settings in Crawford County due to the overall flat lying to gently rolling topography and low relief. Slopes of 2 to 6 percent (9) were assigned to most end moraines exhibiting hummocky terrain. Slopes of 6 to 12 percent (5) and 12 to 18 percent (3) were selected for a limited number of areas where the Sandusky River has steeply downcut the surrounding end moraine nearby Leesville.

## Impact of the Vadose Zone Media

Information on evaluating vadose zone media was obtained primarily from the *Ground Water Resources of Crawford County* (Schmidt, 1981). Open File Bedrock Reconnaissance Maps and Open File Bedrock Topography Maps, based upon U.S.G.S. 7-1/2 minute topographic maps from the ODNR, Division of Geological Survey proved helpful. Vadose zone media ratings from neighboring Seneca County (Smith and Voytek, 1994) and Huron County (Powers et al., 1994) were used as a guideline. The ODNR, Division of Water, Glacial State Aquifer Map and Bedrock State Aquifer Map were an important source of vadose zone media data. The *Soil Survey of Crawford County* (Steiger et al., 1979) provided valuable information on parent materials. The *Glacial Map of Ohio* and *Quaternary Geology of Ohio* (Goldthwait et al., 1961 and Pavey et al., 1999) were useful in delineating vadose zone media. Water well log records on file at the ODNR, Division of Water, were the primary source of aquifer information.

The vadose zone media is a critical component of the overall DRASTIC rating in Crawford County. The rating varies with the restrictive properties of the various glacial materials. The higher the proportion of silt and clay and the greater the compaction (density) of the sediments, the lower the permeability and the lower the vadose zone media are rated.

Sand and Gravel with a rating of (6) was selected as the vadose zone material for a kame/outwash deposit nearby Leesville. Sand and Gravel with a rating of (5) was used for a limited number of end moraine settings adjacent to Seneca County. Till with a vadose zone media rating of (5) was selected for the remaining end moraine settings. Till with a vadose zone media rating of (4) was assigned to till in areas of ground moraine. Silt and Clay with a rating of (4) was applied to areas occupied by intermorainal lakes and areas of alluvial settings. Silt and Clay with a rating of (3) was selected for a limited number of areas adjacent to Seneca County where ground-up black shale fragments caused the till to be unusually fine-grained.

## Hydraulic Conductivity

Information on evaluating the hydraulic conductivity was obtained from the maps and report of the ODNR, Div. of Water, (1970) and the *Ground Water Resources of Crawford County* (Schmidt, 1981). Open File Bedrock Reconnaissance Maps and Open File Bedrock Topography Maps, based upon U.S.G.S. 7-1/2 minute topographic maps from the ODNR, Division of Geological Survey proved helpful. Hydraulic conductivity ratings from neighboring Seneca County (Smith and Voytek, 1994) and Huron County (Powers et al., 1994) were used as a guideline. The ODNR, Division of Water, Glacial State Aquifer Map and Bedrock State Aquifer Map were an important source of hydraulic conductivity data. Water well log records on file at the ODNR, Division of Water, were the primary source of aquifer information. 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; i.e., the more highly rated aquifers have higher values for hydraulic conductivity. All of the sand and gravel aquifers with an aquifer rating of (6) have been given a hydraulic conductivity rating of 300-700 (4) gallons per day per square foot (gpd/$ft^2$). Sand and gravel aquifers with an aquifer rating of (5) were assigned a hydraulic conductivity range of 100-300 gpd/$ft^2$ (2). These ratings reflect the overall fine-grained nature of these sands and the presence of fines.

Devonian and Silurian limestone aquifers with an aquifer media rating of (9) were assigned a hydraulic conductivity rating of 1000-2000 gpd/$ft^2$ (8). These rocks tend to have a high degree of solution and secondary porosity. The other limestone aquifers were given a hydraulic conductivity of 300-700 gpd/$ft^2$ (4). The sandstone, interbedded Sandstone+Shale, and shale aquifers were assigned a hydraulic conductivity rating of 1-100 gpd/$ft^2$ (1).

## APPENDIX B

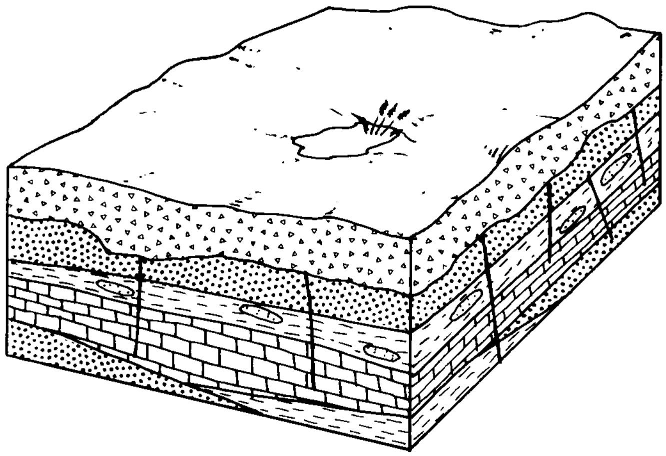
## DESCRIPTION OF HYDROGEOLOGIC SETTINGS AND CHARTS

Ground water pollution potential mapping in Crawford County resulted in the identification of nine hydrogeologic settings within the Glaciated Central Region. The list of these settings, the range of pollution potential index calculations, and the number of index calculations for each setting are provided in Table 11. Computed pollution potential indexes for Crawford County range from 88 to 157.

Table 11. Hydrogeologic settings mapped in Crawford County, Ohio

| Hydrogeologic Settings | Range of GWPP Indexes | Number of Index Calculations |
|---|---|---|
| 7 Aa-Glacial till over interbedded Sandstone+Shale | 88-125 | 10 |
| 7 Ac-Glacial till over solution limestone | 91-151 | 9 |
| 7Ad-Glacial Till over Sandstone | 101-111 | 2 |
| 7 Ae-Glacial till over shale | 94-110 | 10 |
| 7Af-Sand and gravel interbedded in glacial till | 103-140 | 14 |
| 7 C-Moraine | 104-140 | 39 |
| 7 D-Buried valleys | 112-137 | 7 |
| 7 Ec-Alluvium over sedimentary rock | 112-157 | 12 |
| 7 Ed-Alluvium over glacial till | 127-142 | 6 |
| 7 Fc-Intermorainal lake deposits | 95-126 | 13 |

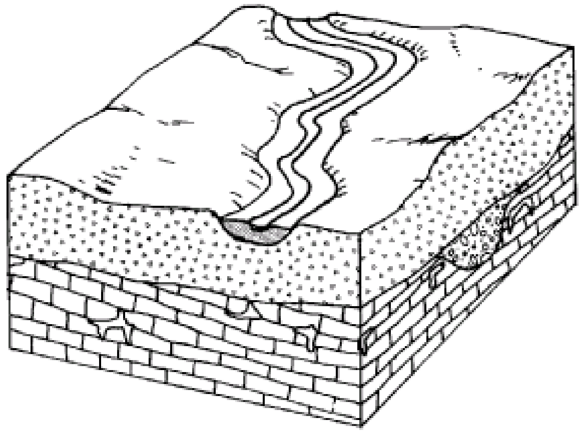
The following information provides a description of each hydrogeologic setting identified in the county, a block diagram illustrating the characteristics of the setting, and a listing of the charts for each unique combination of pollution potential indexes calculated for each setting. The charts provide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



7Aa-Glacial Till over Interbedded Sandstone+Shale

This hydrogeologic setting is limited to the eastern third of Crawford County. The area is characterized by flat lying to gently rolling topography and low relief. The vadose zone is composed of clayey glacial till. The till may be fractured or jointed, particularly in areas where it is predominantly thin and weathered. Depth to water is commonly shallow, averaging less than 35 feet. Soils are generally clay loams. The aquifer is usually fractured, interbedded Mississippian fine-grained sandstones and shales. Yields from the bedrock typically range from 5 to 25 gpm. Recharge is moderately low due to clayey nature of the soils and vadose zone.

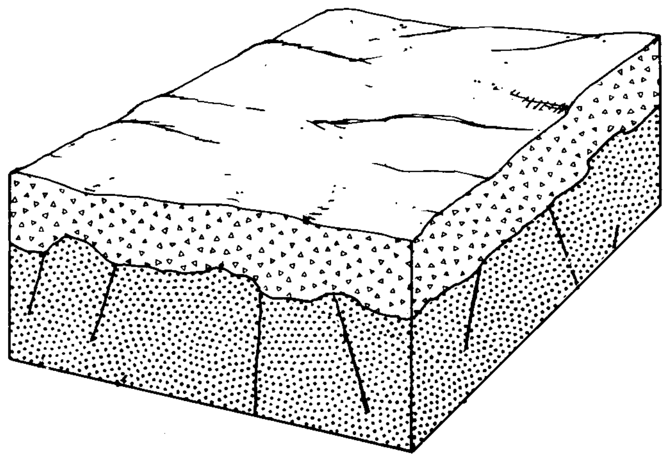
GWPP index values for the hydrogeologic setting of Glacial Till over Interbedded Sandstone+Shale range from 88 to 125, with the total number of GWPP index calculations equaling 10.



7Ac-Glacial Till over Solution Limestone

This hydrogeologic setting is limited to the western third of Crawford County. The area is characterized by flat-lying topography and very low relief. The vadose zone consists primarily of silty to clayey glacial till. The till may be fractured or jointed, particularly in areas where it is predominantly thin and weathered. The aquifer is composed of fractured Silurian and/or Devonian limestones and dolomites. These carbonate rocks may contain significant solution features. Depth to water is typically moderate to deep, ranging from 30 to 60 feet. The depth to water is commonly greater in the limestones than in the other aquifers of the county. Soils are typically clay loams derived from till. Maximum ground water yields greater than 100 gpm are possible from the Silurian Lockport, Tymochtee, Greenfield and Salina Groups. Yields range from 5 to 100 gpm for the Devonian carbonate units. Recharge is moderately low due to clayey nature of the soils and vadose zone.

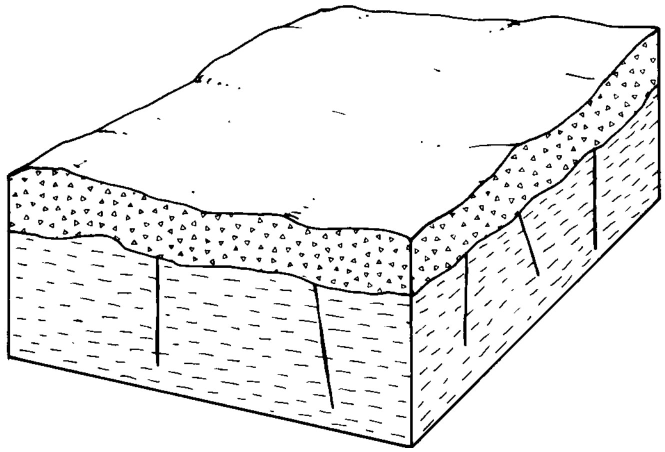
GWPP index values for the hydrogeologic setting of Glacial Till over Solution Limestone range from 91 to 151, with the total number of GWPP index calculations equaling 9.



7Ad Glacial Till over Sandstone

This hydrogeologic setting is limited to a flat-lying ridge of sandstone in eastern Crawford County. Wells completed in this area are shallow and completed in sandstone; shale is not encountered in this vicinity. This setting is characterized by relatively flat-lying to gently rolling topography. The aquifer commonly consists of fractured, fine-grained sandstone. Depths to water are commonly fairly shallow, averaging less than 30 feet. Soils are clay loams derived from the underlying tills. The vadose zone is commonly fractured till. Yields usually average 5 to 25 gpm. Recharge is commonly moderate to low due to low permeability soils and vadose and moderate to shallow depth to water.

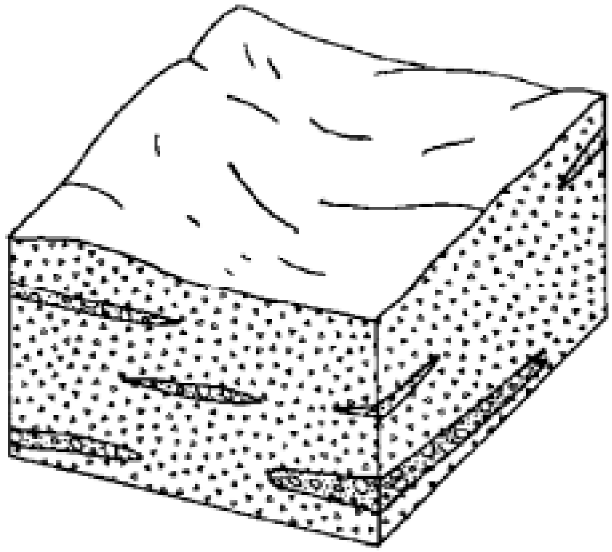
GWPP index values for the hydrogeologic setting of glacial till over sandstone ranges from 101 to 111, with the total number of GWPP index calculations equaling 2.



7Ae-Glacial Till over Shale

This hydrogeologic setting is found in central Crawford County. The area is characterized by flat-lying topography and very low relief. The vadose zone is composed of clayey glacial till. The till may be fractured or jointed, particularly in areas where it is predominantly thin and weathered. Depth to water is typically shallow, averaging less than 20 feet. Soils are generally clay loams. The aquifer is usually fractured, massive black Devonian-age shale or fine-grained, silty Mississippian Bedford Shale. Yields from the shale are typically less than 5 gpm. Recharge is moderately low due to the clayey vadose zone and soils and then impermeable nature of the shale bedrock.

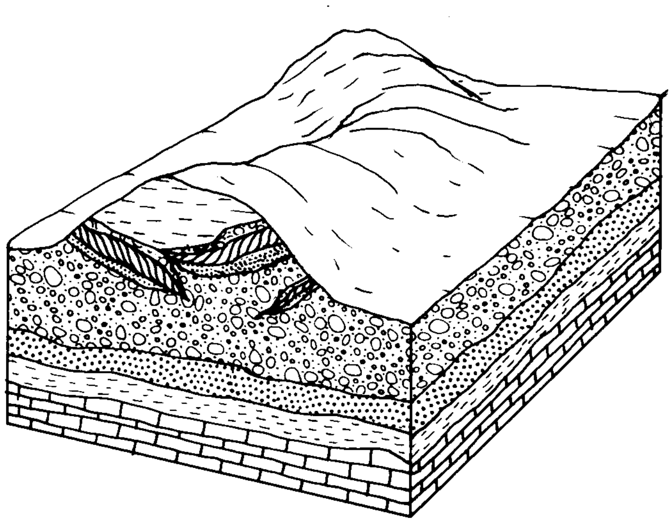
GWPP index values for the hydrogeologic setting of Glacial Till over Shale range from 94 to 110, with the total number of GWPP index calculations equaling 10.



7Af-Sand and Gravel Interbedded in Glacial Till

This hydrogeologic setting is fairly widespread in central and eastern Crawford County. The area is characterized by flat lying to slightly rolling topography. The setting is commonly associated with areas of ground moraine. The vadose zone is composed of silty to clayey glacial till. The till may be fractured or jointed, particularly in areas where it is predominantly thin and weathered. Depth to water is usually shallow, averaging less than 30 feet. Soils are generally clay loams. The aquifer consists of thin lenses of sand and gravel interbedded in the glacial till. Groundwater yields range from 5 to 25 gpm. Recharge is moderately low due to the relatively low permeability of the clayey soils and vadose.

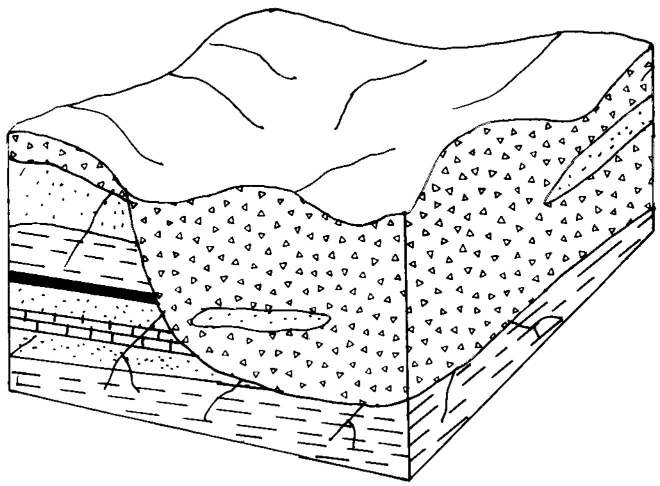
GWPP index values for the hydrogeologic setting of Sand and Gravel Interbedded in Glacial Till range from 103 to 140, with the total number of GWPP index calculations equaling 14.



<u>7C-Moraine</u>

This hydrogeologic setting consists of segments of the numerous end moraines that cross Crawford County. This setting is characterized by hummocky to rolling topography. Relief tends to become steeper near the margins of the moraine, especially if enhanced by the downcutting of an adjacent stream. The aquifer consists of relatively thin sand and gravel lenses interbedded with glacial till within the moraine. These sand and gravel deposits differ as to lateral extent and thickness and are found at variable depths. Yields range from the 5 to 25 gpm. If sand and gravel lenses are not encountered or if they are too thin, wells are completed in the underlying bedrock. The vadose zone is composed of loamy to clayey glacial till. The till may be fractured or jointed, particularly in areas where it is predominantly thin and weathered. Depth to water is variable and depends primarily upon how deep the underlying aquifer is. Soils are commonly clay loams. Recharge is moderately high due to the proximity of sand and gravel lenses to the surface and the amount of weathering and fracturing in the till. The end moraines are the primary local sources of recharge.

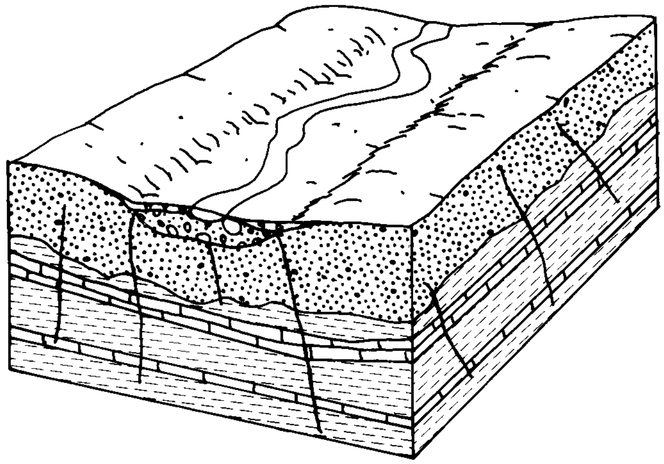
GWPP index values for the hydrogeologic setting of Moraine range from 104 to 140, with the total number of GWPP index calculations equaling 39.



7D-Buried Valley

This hydrogeologic setting is found in the southeastern corner of Crawford County. The buried valley lacks surficial expression and is not overlain by a modern stream. The setting is characterized by overlying flat ground moraine and rolling, hummocky end moraines. The aquifer consists of relatively thin sand and gravel lenses interbedded with glacial till within the moraine. These sand and gravel deposits differ as to lateral extent and thickness and are found at varying depths. Yields range from the 5 to 25 gpm. The vadose zone is composed of loamy to clayey glacial till. The till may be fractured or jointed, particularly in areas where it is predominantly thin and weathered. Depth to water is variable and depends primarily upon how deep the underlying sand and gravel lenses are. Soils are commonly clay loams. Recharge is variable with lower recharge where ground moraine overlies the buried valley and higher recharge where end moraines overlie the buried valley.

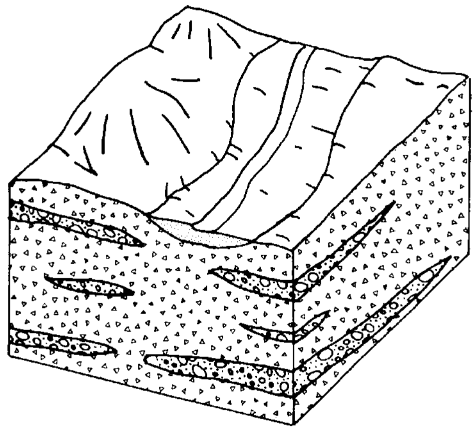
GWPP index values for the hydrogeologic setting of Buried Valley range from 112 to 137, with the total number of GWPP index calculations equaling 7.



7Ec-Alluvium over Sedimentary Rock

This hydrogeologic setting is common throughout Crawford County. This hydrogeologic setting is comprised of flat-lying floodplains and stream terraces containing thin to moderate thicknesses of modern alluvium. This setting is similar to the 7Ed-Alluvium over Glacial Till except that the underlying aquifers consist of bedrock. The vadose zone consists of the silty to clayey alluvial deposits. Depth to water is commonly very shallow, averaging less than 20 feet. The alluvium may be in direct hydraulic connection with the underlying bedrock or there may be thin till or lacustrine deposits in between. Yields vary depending upon the type of underlying bedrock. Soils on the floodplain are typically silt loams derived from the alluvium. Recharge is typically moderately high due to the flat-lying topography, shallow depth to water, the moderate permeability of the soils, and the varying permeability of the underlying bedrock.

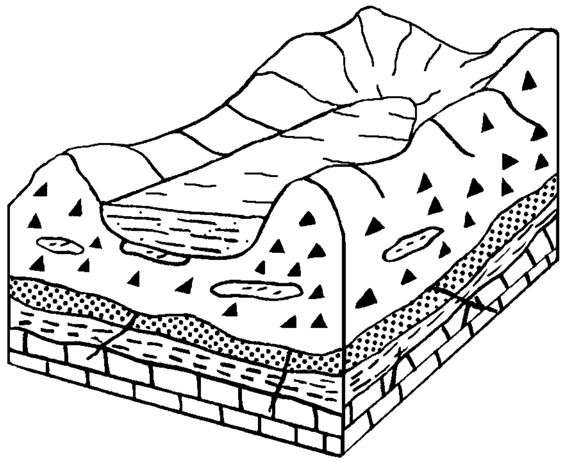
The GWPP index values for the hydrogeologic setting Alluvium over Sedimentary Rocks range from 112 to 157, with the total number of GWPP index calculations equaling 12.



7Ed-Alluvium Over Glacial Till

This hydrogeologic setting is comprised of flat-lying floodplains and stream terraces containing thin to moderate thicknesses of modern alluvium. This setting is similar to the 7Af–Sand and Gravel interbedded in Glacial Till setting except for the presence of the modern stream and related deposits. The setting is also similar to the 7Ec-Alluvium over Sedimentary Rock except that the underlying aquifer consists of shallow sand and gravel lenses instead of bedrock. The stream may or may not be in direct hydraulic connection with the underlying sand and gravel lenses, which constitute the aquifer. The surficial, silty alluvium is typically more permeable than the underlying till. The alluvium is too thin to be considered the aquifer. The vadose zone consists of the silty to clayey alluvial deposits. Soils are silt loams or clay loams. Yields commonly range from 5 to 25 gpm from the sand and gravel lenses. Depth to water is typically shallow with depths averaging less than 20 feet. Recharge is moderately high due to the shallow depth to water, flat-lying topography, and the moderate permeability of the glacial till and alluvium.

The GWPP index values for the hydrogeologic setting Alluvium Over Glacial Till range from 127 to 142, with the total number of GWPP index calculations equaling 6.



<u>7Fc-Intermorainal Lake Deposits</u>

This hydrogeologic setting is characterized by flat-lying topography and varying thicknesses of fine-grained lacustrine sediments. Surficial drainage is typically very poor; ponding is very common after rains. These sediments were deposited in shallow lakes formed between end moraines and the retreating ice sheets before the modern drainage system evolved. This setting occupies many of the low-lying areas within Crawford County. The vadose zone media consists of silty to clayey lacustrine sediments that overlie glacial till. The aquifer consists of thin sand and gravel lenses interbedded in the underlying till or the underlying bedrock. Yields are usually less than 5 gpm for the shale, 5 to 25 gpm for the sand and gravel lenses and sandstones, and over 25 gpm for the limestones. Depth to water is commonly very shallow. Soils are clay loams derived from clayey lacustrine sediments. Recharge in this setting is low due to the relatively low permeability soils and vadose.

GWPP index values for the hydrogeologic setting of Intermorainal Lake Deposits range from 95 to 126, with the total number of GWPP index calculations equaling 13.

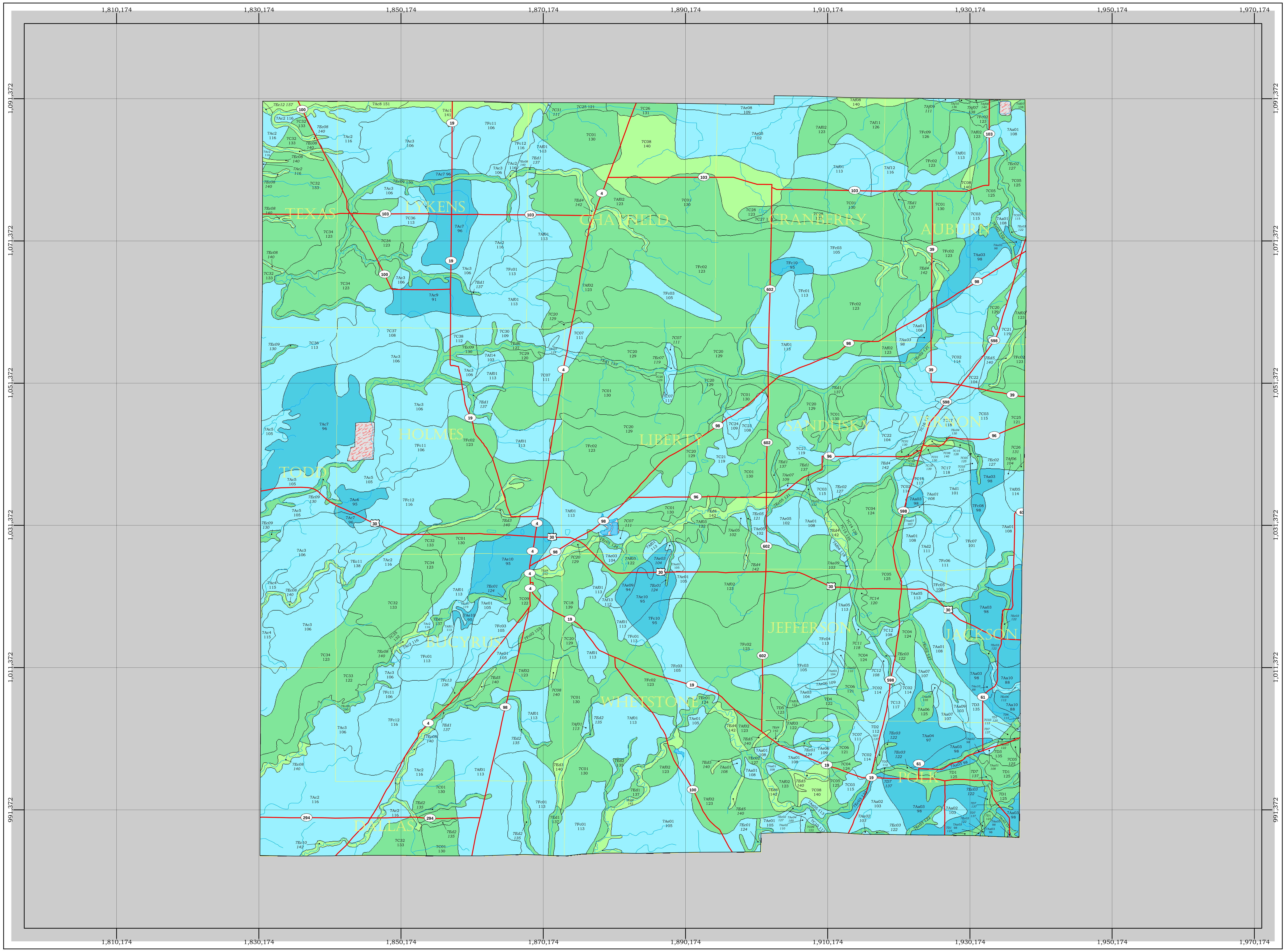
## Table 12. Hydrogeologic Settings, DRASTIC Factors, and Ratings

| Setting | Depth to Water | Recharge (In/Yr) | Aquifer Media | Soil Media | Topography (% Slope) | Vadose Zone Media | Hydraulic Conductivity | Rating | Pesticide Rating |
|---|---|---|---|---|---|---|---|---|---|
| 7Aa01 | 5-15 | 2-4 | Sandstone+Shale | Clay Loam | 0-2 | Till | 1-100 | 108 | 132 |
| 7Aa02 | 15-30 | 2-4 | Sandstone+Shale | Clay Loam | 0-2 | Till | 1-100 | 103 | 126 |
| 7Aa03 | 15-30 | 2-4 | Sandstone+Shale | Clay Loam | 0-2 | Till | 1-100 | 98 | 122 |
| 7Aa04 | 15-30 | 2-4 | Sandstone+Shale | Clay Loam | 2-6 | Till | 1-100 | 97 | 119 |
| 7Aa05 | 5-15 | 2-4 | Sandstone+Shale | Clay Loam | 0-2 | Till | 1-100 | 113 | 136 |
| 7Aa06 | 15-30 | 4-7 | Sandstone+Shale | Sandy Loam | 2-6 | Sand/Gravel | 1-100 | 125 | 154 |
| 7Aa07 | 5-15 | 2-4 | Sandstone+Shale | Clay Loam | 2-6 | Till | 1-100 | 107 | 129 |
| 7Aa08 | 5-15 | 2-4 | Sandstone+Shale | Silty Loam | 6-12 | Till | 1-100 | 105 | 122 |
| 7Aa09 | 5-15 | 2-4 | Sandstone+Shale | Clay Loam | 6-12 | Till | 1-100 | 103 | 117 |
| 7Aa10 | 30-50 | 2-4 | Sandstone+Shale | Clay Loam | 0-2 | Till | 1-100 | 88 | 112 |
| | | | | | | | | | |
| 7Ac1 | 30-50 | 4-7 | Limestone | Clay Loam | 0-2 | Sand/Gravel | 1000-2000 | 141 | 157 |
| 7Ac2 | 15-30 | 2-4 | Limestone | Clay Loam | 0-2 | Till | 300-700 | 116 | 137 |
| 7Ac3 | 30-50 | 2-4 | Limestone | Clay Loam | 0-2 | Till | 300-700 | 106 | 127 |
| 7Ac4 | 15-30 | 2-4 | Limestone | Clay Loam | 2-6 | Till | 300-700 | 115 | 134 |
| 7Ac5 | 30-50 | 2-4 | Limestone | Clay Loam | 2-6 | Till | 300-700 | 105 | 124 |
| 7Ac6 | 50-75 | 2-4 | Limestone | Clay Loam | 2-6 | Till | 300-700 | 95 | 114 |
| 7Ac7 | 50-75 | 2-4 | Limestone | Clay Loam | 0-2 | Till | 300-700 | 96 | 117 |
| 7Ac8 | 15-30 | 4-7 | Limestone | Clay Loam | 0-2 | Sand/Gravel | 1000-2000 | 151 | 167 |
| 7Ac9 | 75-100 | 2-4 | Limestone | Clay Loam | 0-2 | Till | 300-700 | 91 | 112 |
| | | | | | | | | | |
| 7Ad1 | 15-30 | 2-4 | Sandstone | Clay Loam | 0-2 | Till | 1-100 | 101 | 125 |
| 7Ad2 | 5-15 | 2-4 | Sandstone | Clay Loam | 0-2 | Till | 1-100 | 111 | 135 |
| | | | | | | | | | |
| 7Ae01 | 5-15 | 2-4 | Shale | Clay Loam | 0-2 | Till | 1-100 | 105 | 129 |
| 7Ae02 | 5-15 | 2-4 | Shale | Clay Loam | 0-2 | Till | 1-100 | 110 | 133 |
| 7Ae03 | 5-15 | 2-4 | Shale | Clay Loam | 2-6 | Till | 1-100 | 104 | 126 |
| 7Ae03 | 5-15 | 2-4 | Shale | Clay Loam | 2-6 | Till | 1-100 | 104 | 126 |
| 7Ae03 | 5-15 | 2-4 | Shale | Clay Loam | 2-6 | Till | 1-100 | 104 | 126 |
| 7Ae03 | 5-15 | 2-4 | Shale | Clay Loam | 2-6 | Till | 1-100 | 104 | 126 |
| 7Ae04 | 15-30 | 2-4 | Shale | Clay Loam | 0-2 | Till | 1-100 | 100 | 123 |
| 7Ae05 | 5-15 | 2-4 | Black Shale | Clay Loam | 0-2 | Till | 1-100 | 102 | 126 |
| 7Ae06 | 5-15 | 2-4 | Shale | Clay Loam | 2-6 | Till | 1-100 | 109 | 130 |
| 7Ae07 | 15-30 | 4-7 | Black Shale | Clay Loam | 0-2 | Till | 1-100 | 109 | 132 |
| 7Ae08 | 5-15 | 4-7 | Black Shale | Clay Loam | 0-2 | Silt/Clay | 1-100 | 109 | 134 |
| 7Ae09 | 15-30 | 2-4 | Shale | Clay Loam | 2-6 | Till | 1-100 | 94 | 116 |
| 7Ae10 | 15-30 | 2-4 | Shale | Clay Loam | 0-2 | Till | 1-100 | 95 | 119 |
| | | | | | | | | | |
| 7Af01 | 15-30 | 2-4 | Sand + Gravel | Clay Loam | 0-2 | Till | 300-700 | 113 | 134 |
| 7Af02 | 5-15 | 2-4 | Sand + Gravel | Clay Loam | 0-2 | Till | 300-700 | 123 | 144 |

| Setting | Depth to Water | Recharge (In/Yr) | Aquifer Media | Soil Media | Topography (% Slope) | Vadose Zone Media | Hydraulic Conductivity | Rating | Pesticide Rating |
|---|---|---|---|---|---|---|---|---|---|
| 7Af03 | 5-15 | 2-4 | Sand + Gravel | Clay Loam | 2-6 | Till | 300-700 | 122 | 141 |
| 7Af04 | 5-15 | 2-4 | Sand + Gravel | Clay Loam | 6-12 | Till | 300-700 | 118 | 129 |
| 7Af05 | 5-15 | 2-4 | Sand + Gravel | Clay Loam | 0-2 | Till | 100-300 | 114 | 137 |
| 7Af06 | 15-30 | 2-4 | Sand + Gravel | Clay Loam | 0-2 | Till | 100-300 | 104 | 127 |
| 7Af07 | 5-15 | 4-7 | Sand + Gravel | Clay Loam | 0-2 | Silt/Clay | 300-700 | 138 | 159 |
| 7Af08 | 5-15 | 4-7 | Sand + Gravel | Silty Loam | 0-2 | Sand/Gravel | 300-700 | 140 | 164 |
| 7Af09 | 15-30 | 2-4 | Sand + Gravel | Clay Loam | 0-2 | Silt/Clay | 300-700 | 111 | 133 |
| 7Af10 | 5-15 | 4-7 | Sand + Gravel | Muck | 0-2 | Sand/Gravel | 300-700 | 136 | 154 |
| 7Af11 | 5-15 | 2-4 | Sand + Gravel | Clay Loam | 0-2 | Till | 300-700 | 126 | 147 |
| 7Af12 | 15-30 | 2-4 | Sand + Gravel | Clay Loam | 0-2 | Till | 300-700 | 116 | 137 |
| 7Af13 | 15-30 | 2-4 | Sand + Gravel | Clay Loam | 2-6 | Till | 300-700 | 112 | 131 |
| 7Af14 | 30-50 | 2-4 | Sand + Gravel | Clay Loam | 0-2 | Till | 300-700 | 103 | 124 |
| | | | | | | | | | |
| 7C01 | 15-30 | 4-7 | Sand + Gravel | Clay Loam | 0-2 | Till | 300-700 | 130 | 150 |
| 7C02 | 15-30 | 4-7 | Sandstone+Shale | Clay Loam | 2-6 | Till | 1-100 | 114 | 135 |
| 7C03 | 15-30 | 4-7 | Sandstone+Shale | Clay Loam | 0-2 | Till | 1-100 | 115 | 138 |
| 7C04 | 5-15 | 4-7 | Sandstone+Shale | Clay Loam | 2-6 | Till | 1-100 | 124 | 145 |
| 7C05 | 5-15 | 4-7 | Sandstone+Shale | Clay Loam | 0-2 | Till | 1-100 | 125 | 148 |
| 7C06 | 5-15 | 4-7 | Shale | Clay Loam | 2-6 | Till | 1-100 | 121 | 142 |
| 7C07 | 15-30 | 4-7 | Shale | Clay Loam | 2-6 | Till | 1-100 | 111 | 132 |
| 7C08 | 5-15 | 4-7 | Sand + Gravel | Clay Loam | 0-2 | Till | 300-700 | 140 | 160 |
| 7C09 | 5-15 | 4-7 | Shale | Clay Loam | 0-2 | Till | 1-100 | 122 | 145 |
| 7C10 | 15-30 | 4-7 | Shale | Clay Loam | 0-2 | Till | 1-100 | 112 | 135 |
| 7C11 | 5-15 | 4-7 | Sandstone+Shale | Clay Loam | 12-18 | Till | 1-100 | 118 | 127 |
| 7C12 | 15-30 | 4-7 | Sandstone+Shale | Clay Loam | 12-18 | Till | 1-100 | 108 | 117 |
| 7C13 | 15-30 | 4-7 | Sandstone+Shale | Silty Loam | 0-2 | Till | 1-100 | 117 | 143 |
| 7C14 | 5-15 | 4-7 | Sandstone+Shale | Clay Loam | 6-12 | Till | 1-100 | 120 | 133 |
| 7C15 | 5-15 | 4-7 | Sand + Gravel | Clay Loam | 6-12 | Till | 300-700 | 135 | 145 |
| 7C16 | 15-30 | 4-7 | Sandstone+Shale | Clay Loam | 2-6 | Till | 1-100 | 117 | 138 |
| 7C17 | 15-30 | 4-7 | Sandstone+Shale | Clay Loam | 0-2 | Till | 1-100 | 118 | 141 |
| 7C18 | 5-15 | 4-7 | Sand + Gravel | Clay Loam | 2-6 | Till | 300-700 | 139 | 157 |
| 7C19 | 5-15 | 4-7 | Sandstone+Shale | Clay Loam | 0-2 | Till | 1-100 | 128 | 151 |
| 7C20 | 15-30 | 4-7 | Sand + Gravel | Clay Loam | 2-6 | Till | 300-700 | 129 | 147 |
| 7C21 | 30-50 | 4-7 | Sand + Gravel | Clay Loam | 2-6 | Till | 300-700 | 119 | 137 |
| 7C22 | 30-50 | 4-7 | Sandstone+Shale | Clay Loam | 2-6 | Till | 1-100 | 104 | 125 |
| 7C23 | 15-30 | 4-7 | Black Shale | Clay Loam | 2-6 | Till | 1-100 | 108 | 129 |
| 7C24 | 15-30 | 4-7 | Black Shale | Clay Loam | 0-2 | Till | 1-100 | 109 | 132 |
| 7C25 | 15-30 | 4-7 | Sand + Gravel | Clay Loam | 0-2 | Till | 100-300 | 121 | 143 |
| 7C26 | 5-15 | 4-7 | Sand + Gravel | Clay Loam | 0-2 | Till | 100-300 | 131 | 153 |
| 7C27 | 15-30 | 4-7 | Sand + Gravel | Clay Loam | 0-2 | Till | 300-700 | 133 | 153 |
| 7C28 | 30-50 | 4-7 | Sand + Gravel | Clay Loam | 0-2 | Till | 300-700 | 123 | 143 |
| 7C29 | 30-50 | 4-7 | Sand + Gravel | Clay Loam | 0-2 | Till | 300-700 | 120 | 140 |

| Setting | Depth to Water | Recharge (In/Yr) | Aquifer Media | Soil Media | Topography (% Slope) | Vadose Zone Media | Hydraulic Conductivity | Rating | Pesticide Rating |
|---|---|---|---|---|---|---|---|---|---|
| 7C30 | 50-75 | 4-7 | Sand + Gravel | Clay Loam | 2-6 | Till | 300-700 | 109 | 127 |
| 7C31 | 30-50 | 4-7 | Sand + Gravel | Clay Loam | 0-2 | Sand/Gravel | 100-300 | 111 | 133 |
| 7C32 | 15-30 | 4-7 | Limestone | Clay Loam | 0-2 | Till | 300-700 | 133 | 153 |
| 7C33 | 30-50 | 4-7 | Limestone | Clay Loam | 2-6 | Till | 300-700 | 122 | 140 |
| 7C34 | 30-50 | 4-7 | Limestone | Clay Loam | 0-2 | Till | 300-700 | 123 | 143 |
| 7C35 | 15-30 | 4-7 | Limestone | Clay Loam | 2-6 | Till | 300-700 | 132 | 150 |
| 7C36 | 50-75 | 4-7 | Limestone | Clay Loam | 0-2 | Till | 300-700 | 113 | 133 |
| 7C37 | 75-100 | 4-7 | Limestone | Clay Loam | 0-2 | Till | 300-700 | 108 | 128 |
| 7C38 | 50-75 | 4-7 | Limestone | Clay Loam | 2-6 | Till | 300-700 | 112 | 130 |
| 7C39 | 5-15 | 4-7 | Sandstone+Shale | Clay Loam | 2-6 | Till | 1-100 | 127 | 148 |
| | | | | | | | | | |
| 7D1 | 15-30 | 4-7 | Sand + Gravel | Clay Loam | 0-2 | Till | 300-700 | 125 | 146 |
| 7D2 | 15-30 | 2-4 | Sand + Gravel | Clay Loam | 2-6 | Till | 300-700 | 112 | 131 |
| 7D3 | 5-15 | 4-7 | Sand + Gravel | Clay Loam | 0-2 | Till | 300-700 | 135 | 156 |
| 7D4 | 5-15 | 2-4 | Sand + Gravel | Clay Loam | 2-6 | Till | 300-700 | 122 | 141 |
| 7D5 | 5-15 | 2-4 | Sand + Gravel | Clay Loam | 0-2 | Till | 300-700 | 123 | 144 |
| 7D6 | 30-50 | 4-7 | Sand + Gravel | Clay Loam | 0-2 | Till | 300-700 | 115 | 136 |
| 7D7 | 5-15 | 4-7 | Sand + Gravel | Silty Loam | 0-2 | Silt/Clay | 300-700 | 137 | 161 |
| | | | | | | | | | |
| 7Ec01 | 0-5 | 4-7 | Shale | Silty Loam | 0-2 | Silt/Clay | 1-100 | 124 | 151 |
| 7Ec02 | 0-5 | 4-7 | Sandstone+Shale | Silty Loam | 0-2 | Silt/Clay | 1-100 | 127 | 154 |
| 7Ec03 | 5-15 | 4-7 | Sandstone+Shale | Silty Loam | 0-2 | Silt/Clay | 1-100 | 122 | 149 |
| 7Ec04 | 0-5 | 4-7 | Sandstone+Shale | Silty Loam | 0-2 | Silt/Clay | 1-100 | 130 | 157 |
| 7Ec05 | 0-5 | 4-7 | Black Shale | Silty Loam | 0-2 | Silt/Clay | 1-100 | 121 | 148 |
| 7Ec06 | 15-30 | 4-7 | Sandstone+Shale | Silty Loam | 0-2 | Silt/Clay | 1-100 | 112 | 139 |
| 7Ec07 | 5-15 | 4-7 | Shale | Silty Loam | 0-2 | Silt/Clay | 1-100 | 119 | 146 |
| 7Ec08 | 5-15 | 4-7 | Limestone | Silty Loam | 0-2 | Silt/Clay | 300-700 | 140 | 164 |
| 7Ec09 | 15-30 | 4-7 | Limestone | Silty Loam | 0-2 | Silt/Clay | 300-700 | 130 | 154 |
| 7Ec10 | 5-15 | 4-7 | Limestone | Loam | 0-2 | Silt/Clay | 300-700 | 142 | 169 |
| 7Ec11 | 5-15 | 4-7 | Limestone | Clay Loam | 0-2 | Silt/Clay | 300-700 | 138 | 159 |
| 7Ec12 | 15-30 | 4-7 | Limestone | Sandy Loam | 0-2 | Sand/Gravel | 1000-2000 | 157 | 182 |
| | | | | | | | | | |
| 7Ed1 | 5-15 | 4-7 | Sand + Gravel | Silty Loam | 0-2 | Silt/Clay | 300-700 | 137 | 161 |
| 7Ed2 | 5-15 | 4-7 | Sand + Gravel | Clay Loam | 0-2 | Silt/Clay | 300-700 | 135 | 156 |
| 7Ed3 | 5-15 | 4-7 | Sand + Gravel | Clay Loam | 0-2 | Till | 300-700 | 140 | 160 |
| 7Ed4 | 0-5 | 4-7 | Sand + Gravel | Silty Loam | 0-2 | Silt/Clay | 300-700 | 142 | 166 |
| 7Ed5 | 0-5 | 4-7 | Sand + Gravel | Clay Loam | 0-2 | Silt/Clay | 300-700 | 140 | 161 |
| 7Ed6 | 15-30 | 4-7 | Sand + Gravel | Silty Loam | 0-2 | Silt/Clay | 300-700 | 127 | 151 |
| | | | | | | | | | |
| 7Fc01 | 15-30 | 2-4 | Sand + Gravel | Clay Loam | 0-2 | Silt/Clay | 300-700 | 113 | 134 |
| 7Fc02 | 5-15 | 2-4 | Sand + Gravel | Clay Loam | 0-2 | Silt/Clay | 300-700 | 123 | 144 |
| 7Fc03 | 5-15 | 2-4 | Shale | Clay Loam | 0-2 | Silt/Clay | 1-100 | 105 | 129 |

| Setting | Depth to Water | Recharge (In/Yr) | Aquifer Media | Soil Media | Topography (% Slope) | Vadose Zone Media | Hydraulic Conductivity | Rating | Pesticide Rating |
|---|---|---|---|---|---|---|---|---|---|
| 7Fc04 | 5-15 | 2-4 | Sandstone+Shale | Clay Loam | 0-2 | Silt/Clay | 1-100 | 113 | 136 |
| 7Fc05 | 5-15 | 2-4 | Sandstone+Shale | Clay Loam | 0-2 | Silt/Clay | 1-100 | 108 | 132 |
| 7Fc06 | 5-15 | 2-4 | Sandstone+Shale | Clay Loam | 0-2 | Silt/Clay | 1-100 | 111 | 135 |
| 7Fc07 | 15-30 | 2-4 | Sandstone+Shale | Clay Loam | 0-2 | Silt/Clay | 1-100 | 101 | 125 |
| 7Fc08 | 15-30 | 2-4 | Sandstone+Shale | Clay Loam | 0-2 | Silt/Clay | 1-100 | 98 | 122 |
| 7Fc09 | 5-15 | 2-4 | Sand + Gravel | Clay Loam | 0-2 | Silt/Clay | 300-700 | 126 | 147 |
| 7Fc10 | 15-30 | 2-4 | Shale | Clay Loam | 0-2 | Silt/Clay | 1-100 | 95 | 119 |
| 7Fc11 | 30-50 | 2-4 | Limestone | Clay Loam | 0-2 | Silt/Clay | 300-700 | 106 | 127 |
| 7Fc12 | 15-30 | 2-4 | Limestone | Clay Loam | 0-2 | Silt/Clay | 300-700 | 116 | 137 |
| 7Fc13 | 5-15 | 2-4 | Limestone | Clay Loam | 0-2 | Silt/Clay | 300-700 | 126 | 147 |

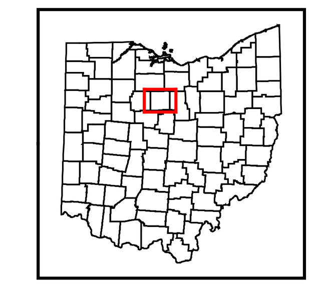



# Ground Water Pollution Potential of Crawford County


*by*

*Michael P. Angle and Chris Russell*

*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 wtih specific hydrogeologic characteristics, which determine the region's relative vulnerability to contamination. Additional information on the DRASTIC system, hydrogeologic settings, ratings, and weighting factors is included in the report.

## Description of Map Symbols

Hydrogeologic Region → 7D24 ← Hydrogeologic Setting

170 ← Relative Pollution Potential

## Legend

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

- Roads
- Streams
- Lakes
- Townships

N

Index Ranges

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

*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
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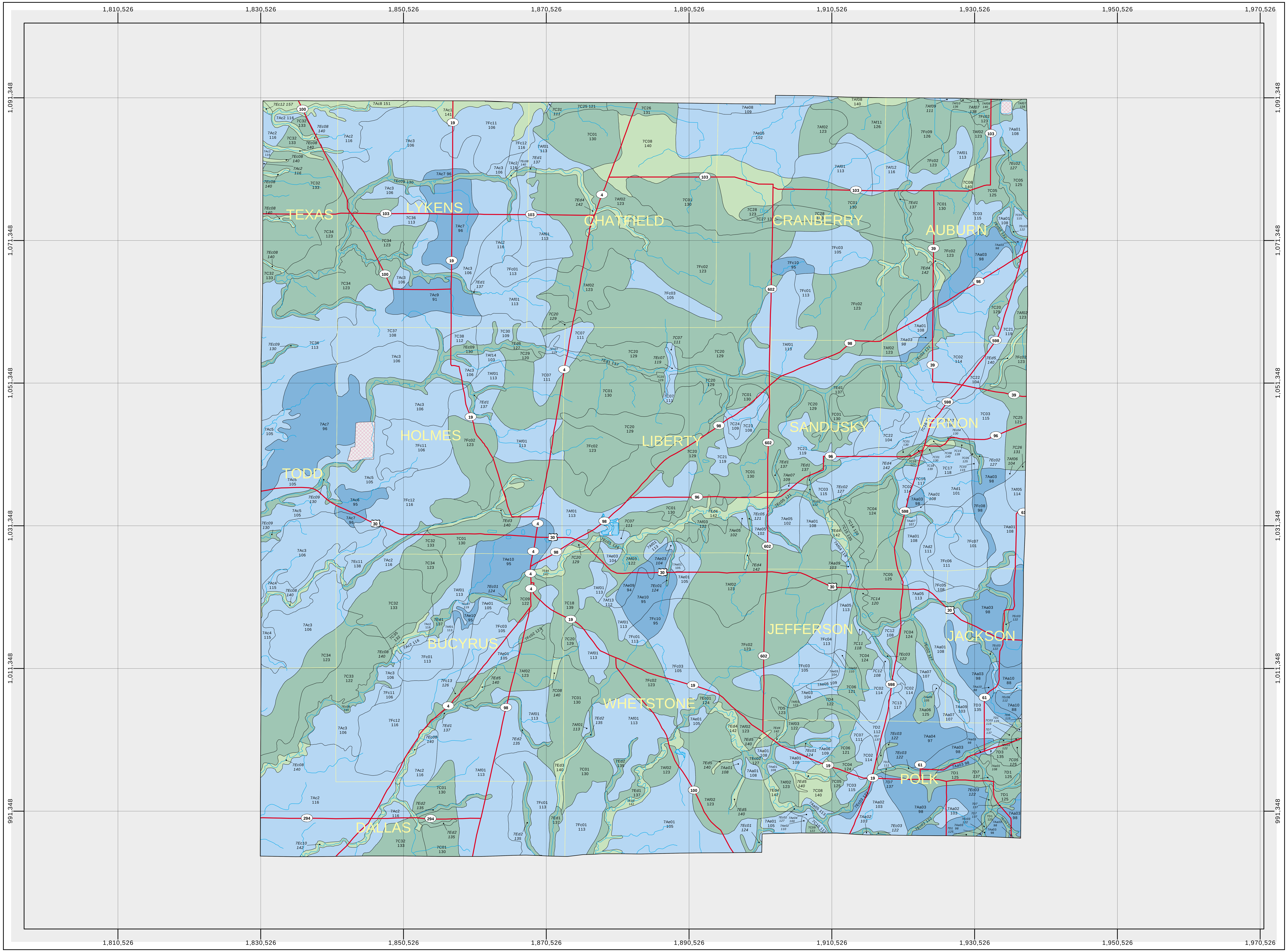


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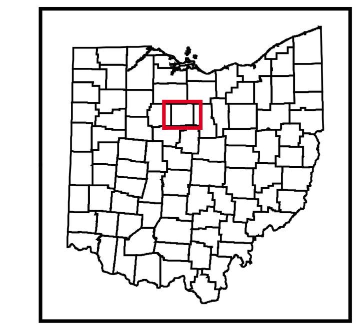

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