Summary of Groundwater Resources and Susceptibility of Green County, Wisconsin

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Green County Land and Water Conservation Committee

Jesse Papez, GISP
GIS Analyst

John M. Rice, PE, PH
Senior Hydrologist

James Wedekind, PG
Senior Geologist

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Section 1
Introduction

This Summary of Groundwater Resources and Susceptibility of Green County has been prepared by TRC Environmental Corporation (TRC) in partnership with Green County. The summary and attached maps are based on well logs and well construction data compiled by Green County staff; publicly available geologic, surface water, spring, and soil data; and geologic field observations of bedrock outcrops by TRC. Sources of the data used and methodologies are outlined in the following sections.

1.1 Background

The general groundwater environment of Green County is presented in Hindall and Skinner (1973) in a report that covered the Pecatonica and Sugar River drainage basins. That report identifies three aquifer units: the sand and gravel aquifer, the Galena-Platteville (Sinnipee) aquifer, and the sandstone aquifer. The sand and gravel aquifer is present in the larger valleys—the Sugar River valley in particular—where the aquifer exceeds 200 feet in thickness and well yields may exceed 1,000 gallons per minute (gpm). Outside of the Sugar River valley, yields are less predictable in wells extracting from the dolomite rock of the Sinnipee and Prairie du Chien Groups. However, the sandstone aquifer is quite productive and provides reliable yields often in excess of 1,000 gpm. The sandstone aquifer supplies groundwater for most of the larger towns and cities in southern Wisconsin, including Monroe, Brodhead, New Glarus, and Monticello.

1.2 Scope

This study was commissioned to synthesize publicly available information, private well construction logs, and related data provided by Green County into a set of groundwater resource maps with greater resolution and accuracy than previously available. This summary report provides information regarding the preparation of the five Green County groundwater resource maps and a guide on how to interpret them. The five attached maps to this report include the following:

- Plate 1 - Bedrock Geology
- Plate 2 - Depth to Bedrock
- Plate 3 - Water Table Elevation
- Plate 4 - Groundwater Recharge
- Plate 5 - Groundwater Susceptibility to Contamination

1.3 Physical Setting

Green County is located in the Western Upland geographic region of south-central Wisconsin, and contains both unglaciated "Driftless Area" on the west and glaciated terrain to the east and south (Martin, 1916; USGS 1976). The county is primarily agricultural, comprised of rolling hills with incised streams that discharge into two south-flowing rivers: the Pecatonica River in the southwest portion and the Sugar River in the east-central portion that serves as the major drainage feature for two-thirds of the county. Surface elevations on the Sugar River range from 755 feet [National Geodetic Vertical Datum of 1988 (NGVD88)] near the Town of Spring Grove to 1,180 feet near the Town of York (Bean, 1951).

Section 2
Methods and Data Sources

2.1 Well Construction Reports

Well construction logs for select high capacity wells were obtained from the Wisconsin Geological and National History Survey (WGNHS). In addition, private well construction logs from the Wisconsin Department of Natural Resources (WDNR) Drinking Water System database and historical well logs (prior to 1988) from WGNHS were also used for reference.

2.2 Springs and Seeps

The water surface elevation of springs and seeps is coincident with the water table at that location. The locations of springs and seeps were obtained from Wisconsin Geological and Natural History publication: WOFR2007-04-DI.

2.3 Surface Waters

Surface water features include streams, rivers, and open water bodies. This information was extracted from the United States Geological Survey (USGS) National Hydrography Dataset, a Geographic Information Systems (GIS)-based set of vector data representing the surface water features in the United States (USGS, 2013).

2.4 Bedrock Outcrop Survey

TRC performed a survey to confirm the elevation and type of bedrock at locations where it was exposed along road cuts and natural bedrock outcrops. The field survey was performed on July 19 and July 24, 2017. Bedrock exposures were logged with a tablet equipped with bluetooth GPS, described in field notes, and photographed.

2.5 Recharge Model

Recharge is the infiltration of rainfall and snow melt through the soil profile to the water table. Recharge is an important component of the water cycle that drives groundwater flow and replenishes groundwater where it is being extracted. Recharge also has the potential to transport contaminants from the surface to the water table and into the potable groundwater flow system. Various factors impact the modeled recharge rate, including daily climate information, surface topography and flow direction, land cover type, and hydraulic properties and storage capacity of soils.

Groundwater recharge was estimated using a soil-water balance (SWB) model developed by USGS. The model relied on the datasets below to estimate annual groundwater recharge. Daily climate information is a tabular dataset, while the other parameters are represented as coded raster (grid) files for the county. All raster files were generated at a 50' x 50' grid resolution.

Climate data used for modeling purposes was provided by the National Oceanic and Atmospheric Administration Climate Data Online dataset. Daily climate information, including precipitation and temperature data from Monroe, Wisconsin, was used for the model (NCDC CDO, 2017). The year 1981 was used for climate data, as it has been determined in Wisconsin state code (NR 151.12) to be a representative climate year and has been used for similar studies in southern Wisconsin.

Land use data for Green County was provided by the Wiscland 2.0 dataset (WDNR, 2016.). This data is derived from Landsat satellite imagery acquired between 2010 and 2014, with an original grid resolution of 30m x 30m. For the SWB model, this was resampled to a 50' x 50' resolution. The land use data used for the SWB model used a 23-category classification in which each category was assigned its own parameters for curve number, interception, and root zone depth.

To determine flow routing of surface water in the model, a flow direction grid was generated from topographic information using GIS software. The information is derived from a 2011 high-resolution LiDAR topographic dataset (Green County, 2016). The LiDAR-based topographic surface was originally provided as a 5' x 5' grid by Green County and was resampled to the 50′ x 50′ model resolution.

The remaining model parameters were derived from soil survey information (NRCS, 2016). Two parameters from the soil survey were used: Hydrologic Group and Available Water Capacity. These parameters represent soil infiltration rates and water-holding capacity. Both of these parameters were converted from their native vector format to 50' x 50' resolution grid files.

The method used to model groundwater recharge are described in further detail in the WGNHS publication B-107, "Groundwater Recharge in Dane County, Wisconsin" (Hart, et. al., 2012).

2.6 Groundwater Susceptibility Model

Groundwater susceptibility modeling was performed using procedures generally consistent with the WDNR's groundwater susceptibility model, which was used previously for a much broader, state-wide study (WDNR, 1983). The Green County model produced a continuous dataset of relative susceptibility ratings across the county.

To construct the model, five geologic, hydrologic, and soil characteristics important for the potential migration of contaminants were given numerical values, weighted and summed for each 25-foot by 25-foot map grid:

1. Soil permeability characteristics
2. Surficial deposits material type/texture
3. Type of bedrock: first consolidated rock encountered (Plate 1)
4. Depth to bedrock: The distance between the ground surface and the top of bedrock (Plate 2)
5. Depth to water: the distance between the ground surface and the first occurrence of saturated soil or rock (calculated using the topography and the water table in Plate 3)

The resultant values were assigned a color and plotted, as shown on Plate 5. The model classified each of these parameters with index values that represent resistance to susceptibility. The resulting values of each contributing parameter were tabulated mathematically with the end value representing potential susceptibility. Higher calculated values indicated greater susceptibility protection and thus were mapped as relative low susceptibility. Low susceptibility scores represented lower relative potential for groundwater impacts, but areas with low scores may still have a higher susceptibility than areas in other counties not reviewed in this study.

The results of this model should be used in coordination with the information presented in the Green County Groundwater Recharge map. Areas that have both high susceptibility scores and high recharge rates may have an enhanced risk for potential groundwater impacts.

Section 3
Geologic Setting and Water Resources

The geology and hydrology of Green County are critical components in the analysis of groundwater susceptibility to contamination. TRC has prepared five plates that illustrate this data for Green County: 1) bedrock geology, 2) depth to bedrock, 3) water table elevation, 4) groundwater recharge, and 5) groundwater susceptibility to contamination.

3.1 Soils

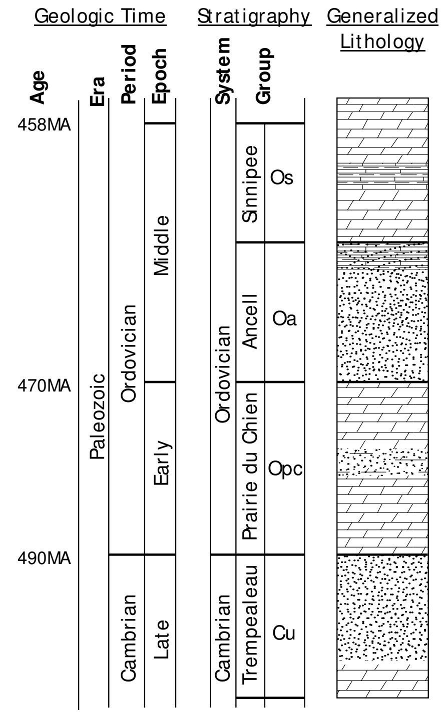
Soils in Green County are formed from glacial sediment (loess, till, lacustrine deposits, and outwash), recent alluvium, and bedrock (sandstone and dolomite). Each one of these parent materials forms different soils depending on the slope, vegetation, and other local features. Soils in the driftless portion of the county are a mixture of loess and residuum of the underlying rocks. Soils in the upland areas are typically thinner and rock outcrops are common. In the eastern, formerly glaciated portion of the county, the soils developed on former stream terraces, often with thicker loess deposits. There are eight soil associations and 75 soil series identified in Green County, as described in Glocker (1974) and summarized in the Green County Land and Water Resource Management Plan (Green County, 2011). Soil permeability is an important predictor of the ability of constituents to migrate to groundwater. In general, clayey soils are less permeable (permeabilities ranging from 0.63 to 2.0 inches per hour), while sandy soils are more permeable and can have permeabilities an order of magnitude higher (Glocker, 1974).

3.2 Pleistocene Glacial Sediments

Green County is unique in Wisconsin not only because the eastern half of the county was glaciated and the western half was not, but because the glaciated portion includes deposits from two earlier glaciations. Glacial deposits are found throughout the eastern part of the county, with loess even covering the Driftless Area. The loess ranges from a few inches to over 6 feet in thickness (Glocker, 1974). Glacial till includes fine grained lake deposits, till, and sand and gravel outwash. Thick deposits (>150 ft) of glacial outwash are found in the Sugar River Valley (Glocker 1974; Hindell and Skinner 1973). The older tills found in the southeastern portion of the county are believed to be from the Illinoian and even the Kansan glacial episodes (Black et al. 1970).

3.3 Bedrock Geology

Plate 1 shows the bedrock geologic map of Green County.



The bedrock geologic map depicts the type of rock that makes up the first layer of solid rock below the ground surface, usually below a column of soil. This type of map displays the rock type that would be seen if all the unconsolidated material above it was removed. A geologic map is important to a groundwater susceptibility study because different rock types vary in their ability to absorb and retain impacts from sources of pollution. In general, carbonate rocks such as limestone and dolomite have a lesser ability to attenuate pollutants than other rocks. This is because carbonate rocks are prone to dissolve, forming fissures, voids, and caves that allow rapid infiltration of surface impacts. Rocks lacking these larger openings can retain infiltration longer, allowing more time for attenuation of the pollutants.

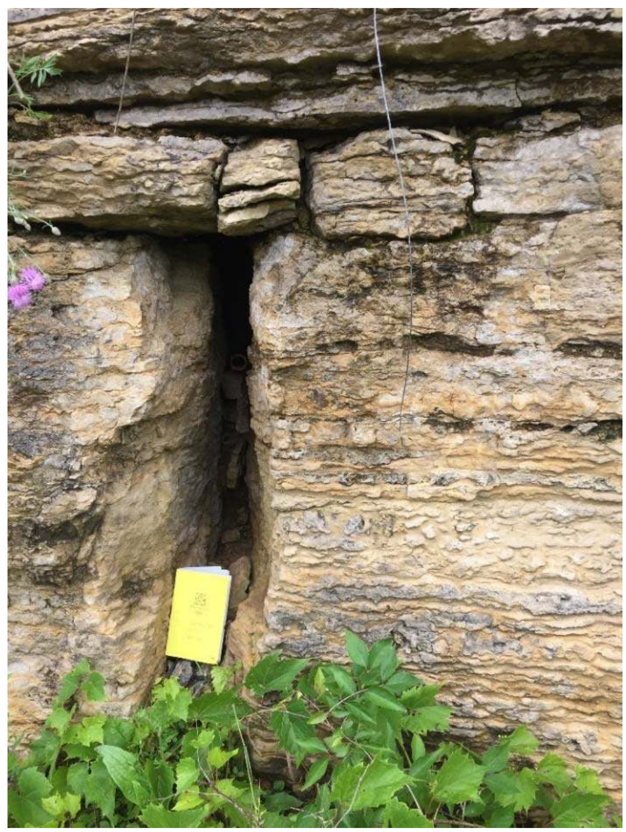
The geologic units shown on Plate 1 are defined by their stratigraphic formation name and rock properties. Most of Green County's surface bedrock geology includes the Sinnipee (dolomite) and Ancell (sandstone) Groups with some isolated exposures of the Prairie du Chien (dolomite) Group and underlying Cambrian sandstone. These rocks are of Ordovician Period, having been deposited in shallow seas approximately 460 million years ago. The bedrock types and properties presented on this map are important in defining infiltration rate and contamination potential for drinking water aquifers within the bedrock.

TRC used private well construction reports provided by the WGNHS and Green County. The geo-located well data, along with its referenced tabular geologic information, was used to derive and map the bedrock surface geology. This information was supplemented by a field reconnaissance of bedrock outcrops, road cuts, quarries, and geologic terrain observation performed by a Wisconsin Professional Geologist. Additionally, state-scale data from WGNHS was used as a reference.

3.3.1 Ordovician Period

Sinnipee Group (Os)

The Sinnipee Group includes three separate dolomite formations: the Galena, Decorah, and Platteville. The Sinnipee underlies the dissected ridges in both the Driftless Area and in many of the gentle ridges of the glaciated eastern part of the county. The Sinnipee rocks are commonly quarried for aggregate and there are numerous active and abandoned quarries in the county that offer excellent exposures of the Sinnipee. The photograph below shows evidence of solutional weathering in the Sinnipee that has resulted in enlarged fractures that could result in rapid transport of groundwater or contaminants. Since the Sinnipee is most often found as upland ridges and is known to be susceptible to contamination, it is not commonly used for water supplies. A boring log from Monroe indicated that the well penetrated 145 feet of the Sinnipee, although it commonly measures over 300 feet in thickness.



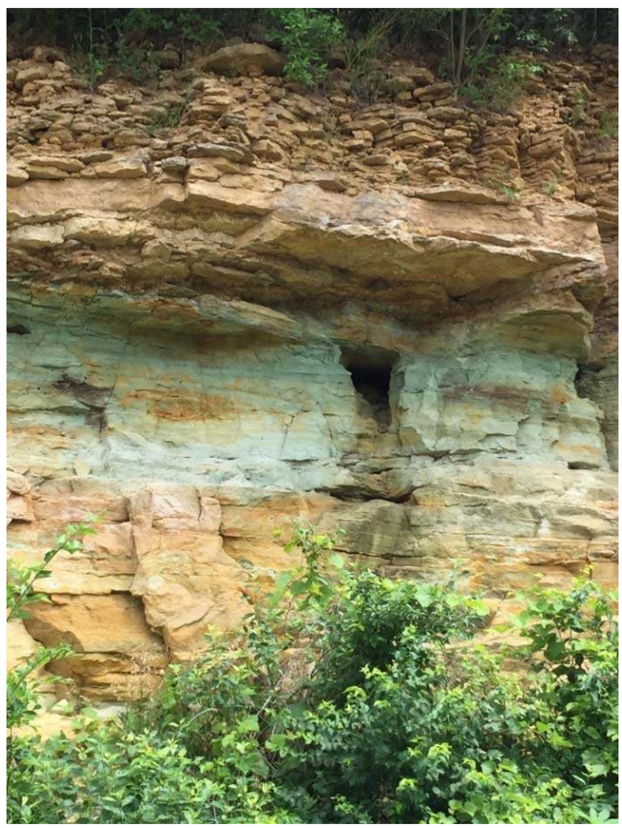
Galena Formation – The Galena formation is dolomite and cherty dolomite. It forms thick to medium beds with a distinctive wavy or mottled weathering pattern and numerous small vugs. The rock is typically found as yellowish brown to buff in color but grey in unweathered exposures. The Galena often contains inclusions of nodular grey or black chert and becomes shaley near its contact with the Decorah. The Galena is typically over 225 feet in thickness in the area (Agnew et. al 1956).

Decorah Formation – The Decorah formation consists of shaley dolomite and shale. The shale is commonly gray or dark gray, but may contain beds that are green, phosphatic and fossiliferous (Brown 1999). The Decorah Formation is typically less than 30 feet in thickness.

Platteville Formation – The Platteville formation is limestone, dolomite and shaley dolomite, blue-gray to buff, fine to medium grained with some chert. Some units of very dense. Fossiliferous limestone are found in the upper portions of the formation, while the lower portions have dense beds of fine grained crystalline dolomite that grades to sandy dolomite at the base of the formation. The thickness of the Platteville is approximately 75 feet in the area (Agnew et al. 1956).

Ancell Group (Oa)

The Ancell Group is two formations: the Glenwood and the St. Peter. The St. Peter is a distinctive white to yellowish-brown sandstone that often forms rounded outcrops in fields and along roadsides. The photograph below shows the contact between the Platteville Formation at top, underlain by the greenish and yellow sandstone of the Glenwood and St. Peter. The St. Peter in Green County also displays evidence of ancient faulting, especially along Highway 104 north of Brodhead (Keen, Lonetti, and Williams, 2015). These faults are not significant to groundwater protection. The thickness of the Ancell is highly variable, ranging from absent in the northern part of the county to over 230 feet in Monroe City Well #5 and over 100 feet at Monticello Village Well #3 and the William Smiley well.



Glenwood Formation – The Glenwood Formation is composed of sandstone, siltstone, and/or shale that is yellow-brown to green in color, and is discontinuous and variable in lithology, texture, and thickness. It includes phosphatic pebbles and some iron staining. The Glenwood is of variable thickness but usually measures less than 20 feet. The photograph above displays evidence of solutional weathering of the Glenwood.

St. Peter Formation – The St. Peter is composed exclusively of clean, well rounded, well sorted quartz sand that is of economic importance for the oil and gas industry. The St. Peter varies widely in thickness across the county, from absent to greater than 230 feet in Monroe City Well #5. The upper unit (Tonti Member) consists of poorly cemented, clean, medium-grained quartz sandstone with typical well-rounded and frosted grains. The St. Peter is commonly internally cross bedded, but often appears as massive in outcrops with few fractures. A lower unit (Readstown Member) is largely yellow-brown sandstone but is also red brown with green shale and shaley sandstone and conglomeritic sandstone with chert.

Prairie du Chien Group

The Prairie du Chien was not observed at the surface in this study, though some outcrops are reported near the Dill community in the southwestern corner of the county. The Prairie du Chien is composed of massive- to medium-bedded dolomite that is light brown to gray in color. There are typically two formations in the area: the Shakopee Formation and Oneota Formation. The Prairie du Chien is absent in Monticello Village Well #3 and Monroe City Well #5, but 70 feet of "Lower Magnesian" light grey and cherty dolomite is reported on the log for New Glarus Village Well #2, and 30 feet of buff dolomite with light colored chert in the William Smiley well log. The Prairie du Chien is a vuggy, sandy dolomite. Light colored nodular chert is common.

3.3.2 Cambrian Period

Cambrian rocks form the deepest and oldest (approximately 550 million years old) sedimentary rocks in the county, extending nearly 1,700 feet below ground surface in the deepest wells and are estimated to extend to an elevation of -3,000 feet NGVD (Bean 1951). These Cambrian rocks form an important aquifer that underlies much of southern Wisconsin and is mined for frac sand in the central portion of the state. The Cambrian rocks are predominately sandstone with some interbedded shale and dolomite. There are three major stratigraphic groups: Trempealeau, Tunnel City, and Elk Mound. These rocks are not exposed at the surface in Green County, but produce groundwater for larger communities and towns including Monroe, Brodhead, and New Glarus.

3.4 Depth to Bedrock

Plate 2 shows the interpreted depth to bedrock across Green County. The depth to bedrock is the distance from ground surface the top of competent bedrock. This can also be interpreted as the soil and overburden thickness above the bedrock surface. This information is presented through contour lines on Plate 2. Depth to bedrock is an important factor in groundwater susceptibility because it identifies how much unconsolidated material rainfall must pass through before reaching the bedrock. This is a key factor in determining the infiltration rate of precipitation to the water table and drinking water aquifers. Because infiltrating water may potentially pass through both the unconsolidated overburden and the bedrock in the process of reaching the water table, the physical properties of both units will factor into groundwater susceptibility.

The depth to the first bedrock unit from the well construction logs was used to determine the depth to bedrock. The field observations of outcrops and terrain were also used to supplement and improve the accuracy of the interpretation of well logs. Locations of potential outcrops and quarries were extracted from the United States Department of Agriculture (USDA) soils data to aid in refining areas of shallow and exposed bedrock surfaces. All of this information was compiled as point depth measurements and interpolated using GIS software. The GIS-generated surface was then reviewed and reinterpreted by geologists to better represent the likely depositional and erosional features of the bedrock surface. This interpretation was used to develop Plate 2. The features shown on Plate 2 are based on a combination of analyzed data and professional interpretation. As such, depths and geometry of features represented on Plate 2 may not precisely match the true conditions of the subsurface.

In combination with the bedrock geologic map (Plate 1), Plate 2 illustrates that much of the county, particularly the northwestern quarter of the county, is characterized by shallow (<10 feet of unconsolidated material) Sinnipee Dolomite. In many river and stream valleys, this top layer dolomite has been eroded to expose the Ancell Group, which is often seen as the St. Peter Sandstone. The eastern part of the county, and particularly along the Sugar River drainage way, is characterized by a series of bedrock valleys that were possibly generated by historical erosion. Throughout this Sugary River region, there is evidence that occasional deeper bedrock units were exposed then redeposited upon, as illustrated by the bedrock geologic units on Plate 1.

3.5 Water Table Elevation

Plate 3 shows the modeled water table map of Green County. The water table elevation map depicts the surface of the first occurrence of saturated unconsolidated material and/or shallow bedrock beneath the ground surface. This is the shallowest depth that groundwater is found and is often different than the elevation of groundwater that may be found in the much deeper drinking water aquifers. Plate 3 uses contour lines to represent the elevation of the water table. Groundwater flows from areas of higher to lower water table elevations. Many variables influence the depth and elevation of the groundwater table. In some cases, the water table may intersect the ground surface and result in springs, seeps, wetlands, or ponds.

Data used to develop and support interpretation includes well construction and water level information supplied by Green County, observations of surface water features, county LiDAR topography data, and USDA soils database information. Information from these sources was synthesized into a consistent and representative conceptual model of groundwater flow Plate 3 uses contour intervals to map the water table surface, as well as significant surface water features in the county, e.g. perennial streams, lakes, and ponds.

There are two general patterns and conclusions that can be drawn from the water table map of the county. First, the surface of the water table is a subdued reflection of the topographic ground surface. As a result, the groundwater divides generally correspond to surface drainage divides. This is typical of the water table surface in humid climates. Second, most of the groundwater in the county generally flows toward the Sugar River and associated tributaries, while groundwater in the southwestern portion of the county flows toward the Pecatonica River.

3.6 Groundwater Recharge

Plate 4 shows the results of the groundwater recharge modeling process. Plate 4 and associated analysis provide a modeled estimate of the rate that groundwater is replenished by rainfall and surface water runoff. Various factors impact the recharge rate including surface topography, land cover type, and soil and overburden types. The results of the analysis are mapped using a color gradient that show the variation in recharge rates across the county. This information is important to use in conjunction with the susceptibility information discussed in Section 3.7 when planning future land use.

The permeability of the surface soils has the greatest effect on the modeled groundwater recharge rate. Recharge is highest in areas with surface soils that are well drained and have a higher permeability. Poorly drained soils have lower infiltration rates, which result in lower predicted groundwater recharge. In general, higher recharge rates are predicted along the Sugar River valley and in the unglaciated area south and west of Monroe.

3.7 Groundwater Contaminant Susceptibility

Plate 5 shows the relative groundwater susceptibility to contamination for Green County. Groundwater contaminant susceptibility is defined as "the ease with which water (and presumably contaminants) at the surface can reach the water table" (Schmidt, 1987). This map draws from the information presented on Plates 1 to 4 to calculate a relative index number indicating contamination susceptibility. Plate 5 is an important planning tool for the county assess new industrial and agricultural developments and communication decisions to the public.

This map shows the general ability of soil and rock to facilitate the movement of water and contaminants from the land surface to the shallow groundwater and water table. This map, in combination with Plates 1 to 4 and this summary text can be used as a resource to guide planners and other parties to areas of potential concern that may require further study. The information in this report, combined with additional resources, such as detailed land use maps, groundwater quality data, contamination source information, etc. can be used to facilitate Green County groundwater management and land use decisions.

The information provided in this report and Plates 1 to 5 is not intended to predict areas that will be or are contaminated, or conversely to predict areas that are safe from contamination. These maps and related information do not replace site-specific data evaluation.

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Attachments
Plates 1 through 5

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