SURFICIAL GEOLOGY AND AQUIFER SENSITIVITY OF THE GIBSON CITY EAST 7.5-MINUTE QUADRANGLE, FORD AND CHAMPAIGN COUNTIES, ILLINOIS

ANDREW L. WATSON

50 Pages

To better characterize the distribution of Holocene and Late Quaternary deposits and begin to assess the hydrogeology and contamination potential in the Gibson City East 7.5-Minute Quadrangle, Surficial Geologic and Aquifer Sensitivity maps were created. Soils data from the U.S. Department of Agriculture, geologic logs from various types of borings, including water wells, oil and gas explorations boreholes, and test holes for underground structures and building of infrastructure, and LiDAR topographic data presented as gridded DEM hillshades were compiled and analyzed using ESRI's ArcGIS 10.6.1 to determine the extent and thickness of the geologic materials on the land surface, and in the shallow subsurface. Field verification of the geologic materials was completed after initial data compilation in GIS. Aquifer sensitivity to contamination was estimated based primarily on the depth to the first aquifer unit, aquifer thickness, and the lithology of the aquifer materials. In general, deeply buried and thinner aquifer units are less susceptible to contamination, while shallower, thicker aquifer units are more susceptible to contamination. The surficial geologic mapping identified different lithologies that were classified to five lithostratigraphic units: the Cahokia Formation, Equality Formation, Henry Formation, and Yorkville and Batestown Members of the Lemont Formation. The southeast to northwest trending Illiana Morainic System is the most prominent feature in the study area and delineates the maximum extent of the glaciers during the Livingston Phase of glaciation. Postglacial deposits assigned to the Cahokia Formation are mapped along channels and drainage ways downslope of the moraine. These deposits interfinger and overlie with glacial outwash of the Henry Formation. The Batestown till is present in the southwest and southeast corners of the map beyond the margin of the Lake Michigan Lobe. The potential of shallow aquifer units to contamination are delimited by 9 classes: most sensitive to least sensitive, (A3 to E1), respectively. In general, the areas of least sensitivity are located over the Illiana Morainic System, whereas the greatest potential to contamination occurs where the thickest deposits of the Henry Formation and Cahokia Formation lie at or just below the land surface.

KEYWORDS: Surficial geology; Aquifer sensitivity

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SURFICIAL GEOLOGY AND AQUIFER SENSITIVITY OF THE GIBSON CITY EAST 7.5-MINUTE QUADRANGLE, FORD AND CHAMPAIGN COUNTIES, ILLINOIS

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A. L. W

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CHAPTER I: INTRODUCTION AND BACKGROUND

Introduction

Geologic maps are crucial for making sound, unbiased, and cost-effective land-use decisions. These maps help to establish the geologic framework of areas determined to be vital to the economic, social, environmental, or scientific welfare of communities. Geologic mapping priorities are determined by various groups, including government agencies, advisory panels and quasi-governmental stakeholder groups, representing a broad range of end-users of geologic maps, based on areas of multiple issue need or areas of compelling single-issue need; and where mapping is required to solve critical earth science problems (National Geologic Mapping Act, 1992).

Detailed geologic maps are needed in east-central Illinois as the majority of the region's water resources come from groundwater. The Mahomet Aquifer System, which is found within the Mahomet Bedrock Valley and includes both the Mahomet Aquifer and the overlying aquifer and non-aquifer units, is the principal groundwater resource in east-central Illinois. The Mahomet Aquifer alone provides an estimated 53 million gallons per day (mgd) of drinking water to approximately 120 public water supplies and thousands of rural wells, together serving over 500,000 people (US EPA, 2015). In 2015, the U.S. Environmental Protection Agency designated the Mahomet Aquifer System, which includes the Mahomet Aquifer, a sole-source aquifer (US EPA, 2015). Because of the aquifer system's significance to the communities it serves, the Illinois State Geological Survey designated the eastern Mahomet Bedrock Valley a priority geologic mapping area (Figure 1). Detailed geologic maps can provide a more precise characterization of the materials comprising the Mahomet Aquifer System, so that more informed land use decisions can be made to better protect this invaluable resource. Additionally, these maps will allow stakeholders to identify areas where the subsurface is more prone to contamination, such as areas overlain by sand and gravel. With this information, agricultural practices and city development can be planned to address these concerns.

Figure 1: Map of the Mahomet Aquifer in east-central Illinois. The ISGS priority mapping area is delineated by the red outline. The red diagonal line in Champaign County represents the approximate location of the cross section in Figure 12. (Image provided courtesy of Roadcap, G.S., Knapp, H.V., Wehrmann, H.A., and Larson, D.R., 2011, Meeting east-central Illinois water needs to 2050: Potential impacts on the Mahomet Aquifer and surface reservoirs: Illinois State Water Survey, Contract Report 2011-08, Illinois State Water Survey, Prairie Research Institute, University of Illinois at Urbana-Champaign."

Because the majority of water wells in east-central Illinois are constructed in unconsolidated glacial deposits, geologic maps outlining their distribution are necessary. These maps are made from a combination of data from field observations, soil surveys, borehole logs, or remotely-sensed data (e.g., light detection and ranging (LiDAR) data and satellite and aerial imagery). These data are typically compiled in GIS software for analysis, interpretation, and creation of the map. Surficial geologic maps form a basis upon which other derivative maps can be made for specific purposes, such as groundwater management, exploration for mineral resources, or mitigation of natural hazards.

In east-central Illinois, sources of groundwater contamination can be non-point sources, such as fertilizer and pesticide applied on agricultural lands, chloride dissolution from road salting, and from point sources, specifically leaking underground storage tanks and pipelines, and leachate from landfills and dumps (Berg, 2001). Aquifer sensitivity maps can be created to help in the assessment of contamination potential. Aquifer sensitivity refers to the relative ease with which a contaminant can move from the land surface into the subsurface (US EPA, 1993). The maps are based on information from surficial geologic maps, borehole geologic logs, and surface and downhole geophysical surveys.

These maps have been used by land-use planners and government agencies for identifying areas of high risk and making decisions for future development (Central Great Lakes Geologic Mapping Coalition, 1999). In Illinois since the mid-1980s, these maps were compiled at state, regional and county scales to assist in landfill siting, prioritizing areas for groundwater monitoring, selecting candidate areas for development of low-level radioactive waste disposal facilities, and studying the potential effects of agricultural chemicals on shallow groundwater quality (Rine et al., 2006; Berg et al., 1984; Shafer, 1985; Keefer and Berg, 1990; Keefer, 1995). This effort includes mapping for aquifer sensitivity in parts of 11 counties (e.g., Berg and Abert, 1999; Berg et al., 2000; Berg et al., 2015; Dey et al., 2007; Johnstone, 2003; McGarry and Grimley, 1997; McGarry and Riggs, 2000). The Illinois State University faculty and graduates have contributed to this effort, in the Ottawa Quadrangle (Hart and Malone, 2003) and Marseilles Quadrangle (Walls and Malone, 2004).

Objectives

The goal of this study was to provide a better understanding of the distribution of Quaternary and Holocene (postglacial) deposits within the Gibson City East 7.5-Minute Quadrangle. A surficial geologic map of the Quadrangle was created as part of this effort. Furthermore, to begin to evaluate the hydrogeology and contamination potential of the glacial deposits found in the quadrangle, an aquifer sensitivity map was developed.

Study Area

The Gibson City East 7.5-Minute Quadrangle is located in southern Ford County and northern Champaign County (Figure 2). The map area primarily includes rural agricultural land, but does contain part of Gibson City. The mapping completed for this study builds upon the previous work in adjacent areas by Stumpf (2014), Rickels et al. (2016), and Wirth et al. (2018).

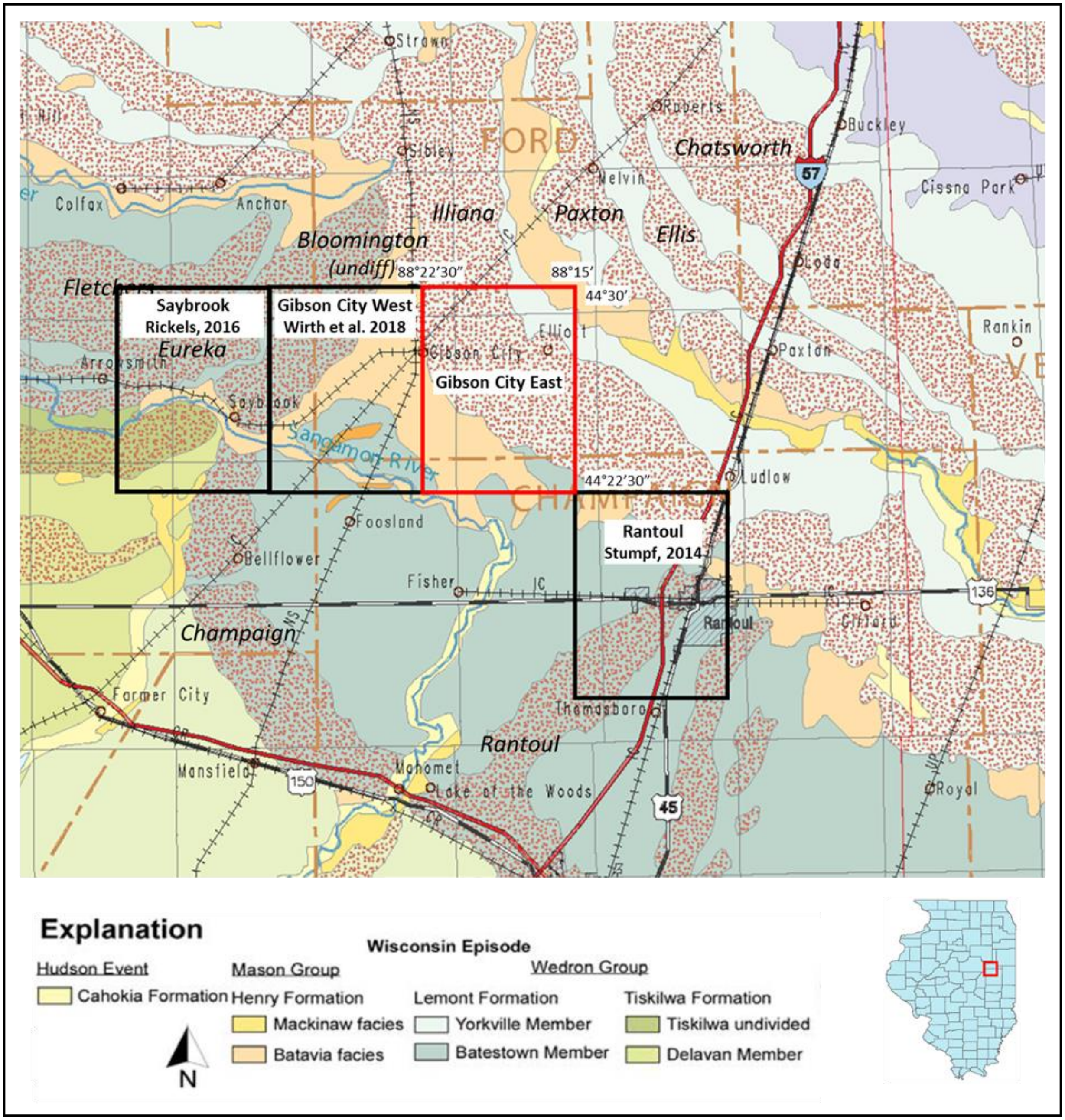


Figure 2: Surficial Geologic Map of east-central Illinois with the study area outlined in red. (From Stiff, B.J., digital adaptation, 2000, Surficial deposits of Illinois: Illinois State Geological Survey, Open File Series 2000-7, map, scale 1:500,000. Copyright © 2000 University of Illinois Board of Trustees. Used by permission of the Illinois State Geological Survey).

Geologic Setting

This section will provide a general overview of the surficial deposits and geomorphic history of the study area, as presented in the literature. The specific findings from this study will be presented in the Results section. Surficial deposits within the Gibson City East Quadrangle are a product of glacial and postglacial processes that occurred during the Hudson and Wisconsin Episodes. The Hudson Episode represents modern and older postglacial deposits dating back to approximately 14,700 years before present (BP) (Stumpf, 2018; Curry et al, 2018). The Cahokia Formation, which includes deposits of poorly sorted sand, silt, clay, and gravel found on floodplains and in river channels are the only sediments in the Quadrangle dating to the Hudson Episode. The thickness of the Cahokia Formation varies, but was found to be up to ~4.5 meters (15 feet) thick in the adjacent Rantoul Quadrangle (Stumpf, 2014). The Peoria Silt of the Hudson Episode likely blankets much of the area within the Quadrangle with one to three feet of wind-blown clayey silt, but it is not typically included on surficial geologic maps in adjacent areas as it is less than five feet thick.

The glacial sediments from the Wisconsin Episode found in the Gibson City East Quadrangle were deposited by the Decatur Sublobe that comprised the Lake Michigan Lobe of the Laurentide Ice Sheet (Johnson et al, 1986). The advance of the Decatur Sublobe into east–central Illinois occurred during the Michigan Subepisode approximately 24,000 – 14,700 years BP (Curry et al, 2018). The Michigan Subepisode represents the last major glaciation during the latter part of the Wisconsin Episode. Eight phases of ice margin advance and retreat of the Lake Michigan Lobe occurred during this time period (Figure 3). Of these phases, only glacial tills of the Putnam and Livingston Phases that occurred between ~24,200 – ~22,200 years BP and ~22,200 – ~21,100 years BP, respectively (Curry et al, 2018) are found within the Quadrangle.

Diamicton forming the Illiana Morainic System, the most prominent landform in the Quadrangle (Figure 2), was deposited during the Livingston Phase. This diamicton (interpreted as till) is classified to the Yorkville Member, of the Lemont Formation (Hansel and Johnson, 1996). The till is characterized by its dark grey color, and silty clay to silty clay loam texture. The till was found to be between ~3 to ~9 meters (10 - 30 feet) thick in the adjacent Rantoul Quadrangle (Stumpf, 2014). Southwest of the Illiana Morainic System, deposits of the Equality Formation, the Batavia Member of the Henry Formation, and the Batestown Member of the Lemont Formation occur at the land surface. The Equality Formation consists of brown to gray to reddish-brown silt and clay that is bedded to laminated that was deposited in a proglacial lacustrine environment. The deposits are ~1.5 to ~6 meters (5 - 20 feet) thick in the Rantoul Quadrangle (Stumpf, 2014) but have been found to be up to approximately 20 meters (65 feet) thick in east-central Illinois (Willman and Frye, 1970). These sediments were deposited late into the Putnam Phase as the glaciers receded northward. These glacial lakes could have persisted into the Livingston Phase, and even into postglacial time. The Batavia Member of the Henry Formation includes deposits of sand and gravel (glacial outwash) that contains some beds of silt (Hansel and Johnson, 1996). The outwash was deposited along the ice margin as the Illiana Morainic System was being formed to the east and north, and interpreted to be associated with the later part of the Livingston Phase. Outwash ranges considerably in thickness, from upwards of 65 meters (213 feet) in major valleys to less than one meter (4 feet) in fans along moraine fronts, but is only up to ~7.6 meters (25 feet) thick in the Rantoul Quadrangle (Stumpf, 2014). The oldest surficial deposits in the Gibson City East Quadrangle, diamicton classified to the Batestown Member, was deposited during the latter part of the Putnam Phase (Hansel and Johnson, 1992) when the Laurentide Ice Sheet retreated north of Champaign County and readvanced to the Champaign Moraine. This till is distinguished from the Yorkville Member by its slightly coarser texture (silt loam to loam) (Hansel and Johnson, 1996). The Batestown Member was found to be between ~7.6 to ~22.8 meters (25 - 75 feet) thick in the Rantoul Quadrangle (Stumpf, 2014).

In the subsurface, the Tiskilwa Formation till underlies the Batestown Member till (Figure 4). The Tiskilwa Formation till was deposited during the Shelby Phase approximately ~24,000 to 22,000 years BP (Stumpf, 2018; Curry et al, 2018). The diamicton is defined as reddish grey to grey clay loam to loam (Hansel and Johnson, 1996).

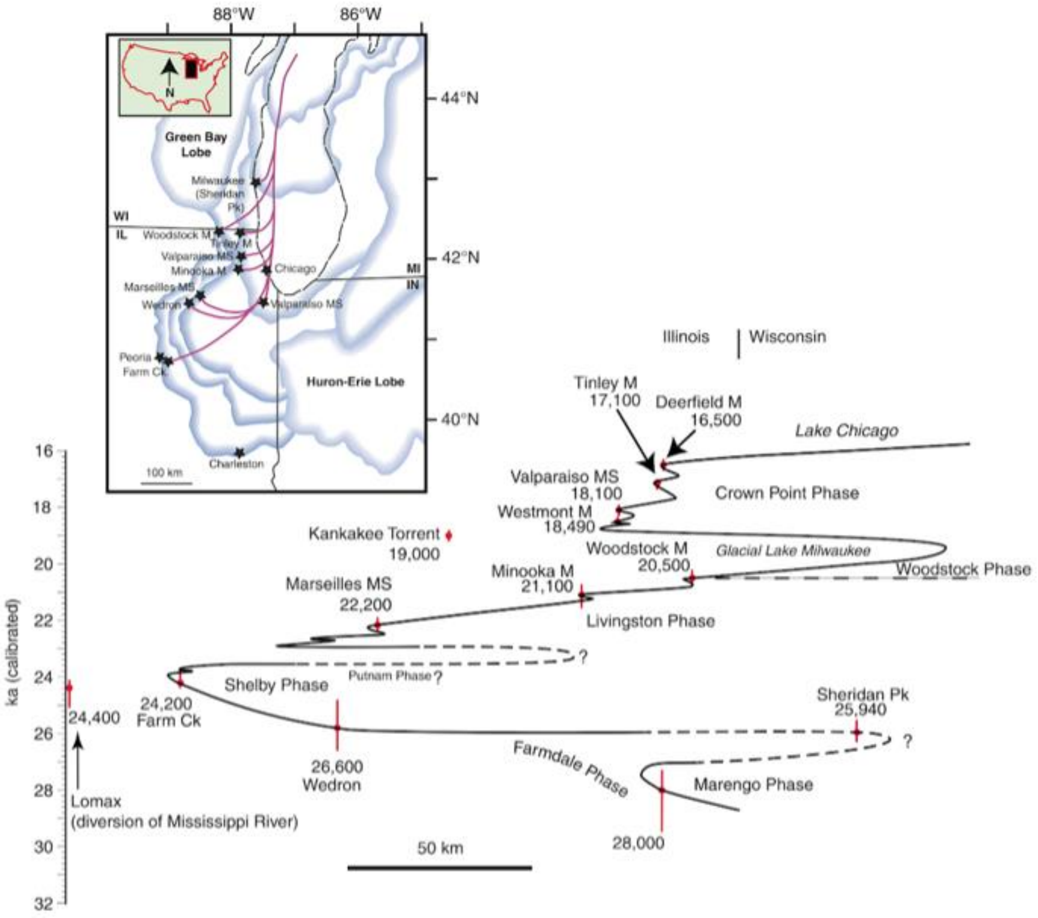


Figure 3: Time-distance diagram for the Lake Michigan Lobe. (From Curry et al, 2018).

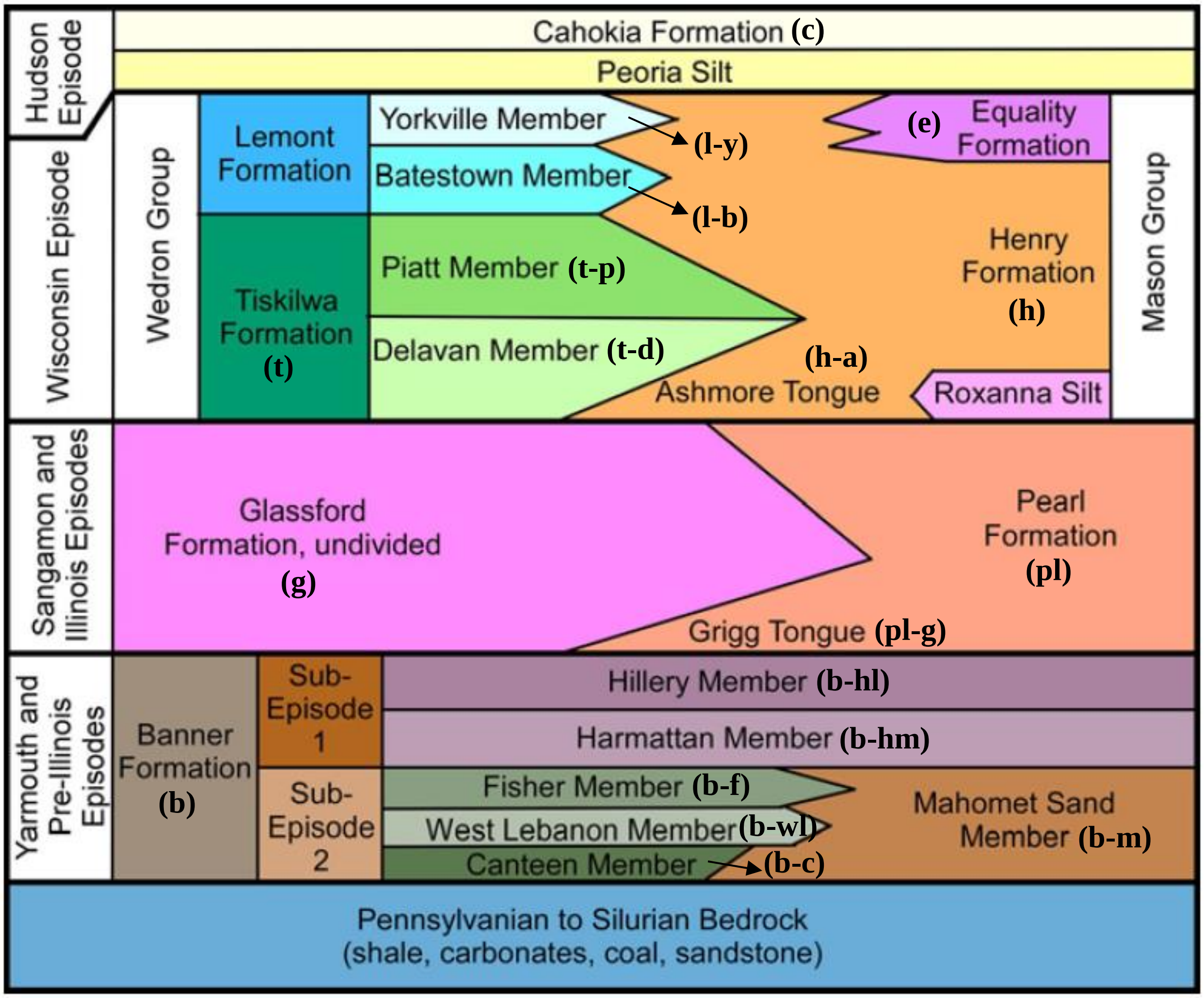
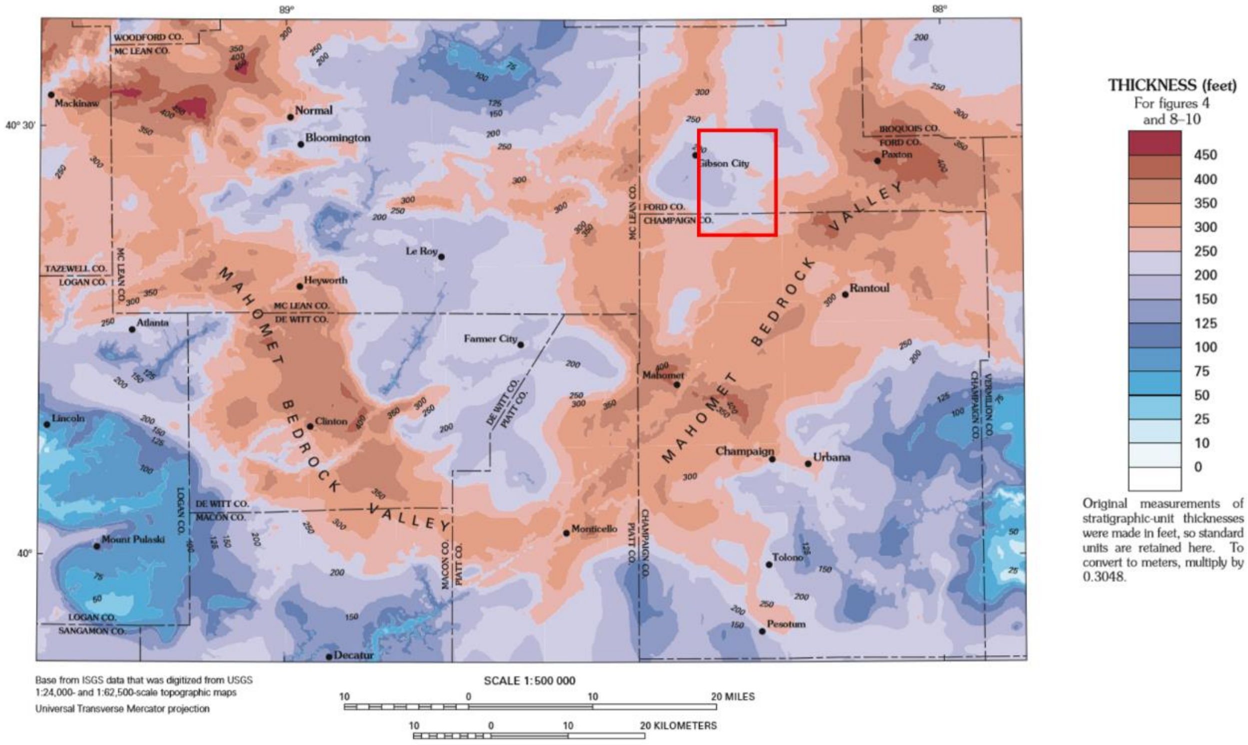


Figure 4: Generalized lithostratigraphy of Quaternary-age sediments in east-central Illinois (After Stumpf A.J., and Atkinson L.A., 2015, Geologic cross sections across the Mahomet Bedrock Valley, Champaign, Ford, McLean, Piatt, and Vermilion Counties, Illinois: Illinois State Geological Survey, Illinois Map IMAP 19, scale 1:48,000, Correlation of Mapping Units. Copyright © 2015 University of Illinois Board of Trustees. Used by permission of the Illinois State Geological Survey.

Beneath deposits of the Wisconsin Episode lies diamicton (tills) of the Vandalia Member (Glasford Formation) and outwash deposits of the Pearl Formation, deposited during the Illinois Episode (Stumpf and Dey, 2012). Interstratified layers of sand and gravel within the upper part of the Vandalia Member form aquifers, but they have a limited areal extent. Pre-Illinois Episode deposits of the Banner Formation compose the lower part of the glacial sedimentary succession (Figure 4). The Banner Formation includes the uppermost Tilton Member, followed by diamicton (tills) of the Hillery and Harmattan Members, and glacial outwash of the Mahomet Sand Member. The Mahomet Aquifer is composed of deposits classified to the Mahomet Sand Member. Silurian to Devonian bedrock, primarily limestone and dolomite, underlie the Quaternary-age deposits. The thickness of preglacial, glacial, and postglacial deposits overlying the bedrock ranges from approximately 60 to 90 meters (200 to 300 feet) within the Gibson City East Quadrangle, with thicker deposits over the Mahomet Bedrock Valley (Soller et al. 1999), (Figure 5).



Original measurements of stratigraphic-unit thicknesses were made in feet, so standard units are retained here. To convert to meters, multiply by 0.3048.

Figure 5: Isopach map of glacial and postglacial deposits in east-central Illinois (modified from Soller et al. 1999). The red box outlines the study area.

CHAPTER II: METHODOLOGY

Surficial Geology

As part of this study, a surficial geologic map was developed for the Gibson City East 7.5-Minute Quadrangle to better visualize the distribution of glacial and postglacial deposits at the land surface and in the shallow subsurface in the study area. Mapping was completed at the 1:24,000 scale.

The first step in the developing the surficial geologic map was to assemble a parent material map of the soils by compiling United States Department of Agriculture (USDA) – Natural Resource Conservation Service (NRCS) soil data for Ford and Champaign counties (NRCS, 2003; NRCS, 2004) that are available as a shapefile. The shapefile was imported into ESRI’s ArcMap ™ software (Version 10.6.1), and the vector data were clipped to the boundary of the Quadrangle (Figure 6). The polygons were then coded by parent material. To do this, an Excel spreadsheet was exported with the attribute table of the soils shapefile. Each soil code was matched with its corresponding parent material listed in the Custom Soil Report (Table 1). This Excel file was then joined to the attribute table of the soil shapefile, and the soil polygons were categorized by parent material in the symbology of the shapefile allowing each soil polygon to be displayed representing its parent material. When delineating the parent materials, only deposits at least five feet (1.5 m) thick were included. When deposits did not meet this specification, the underlying unit was used.

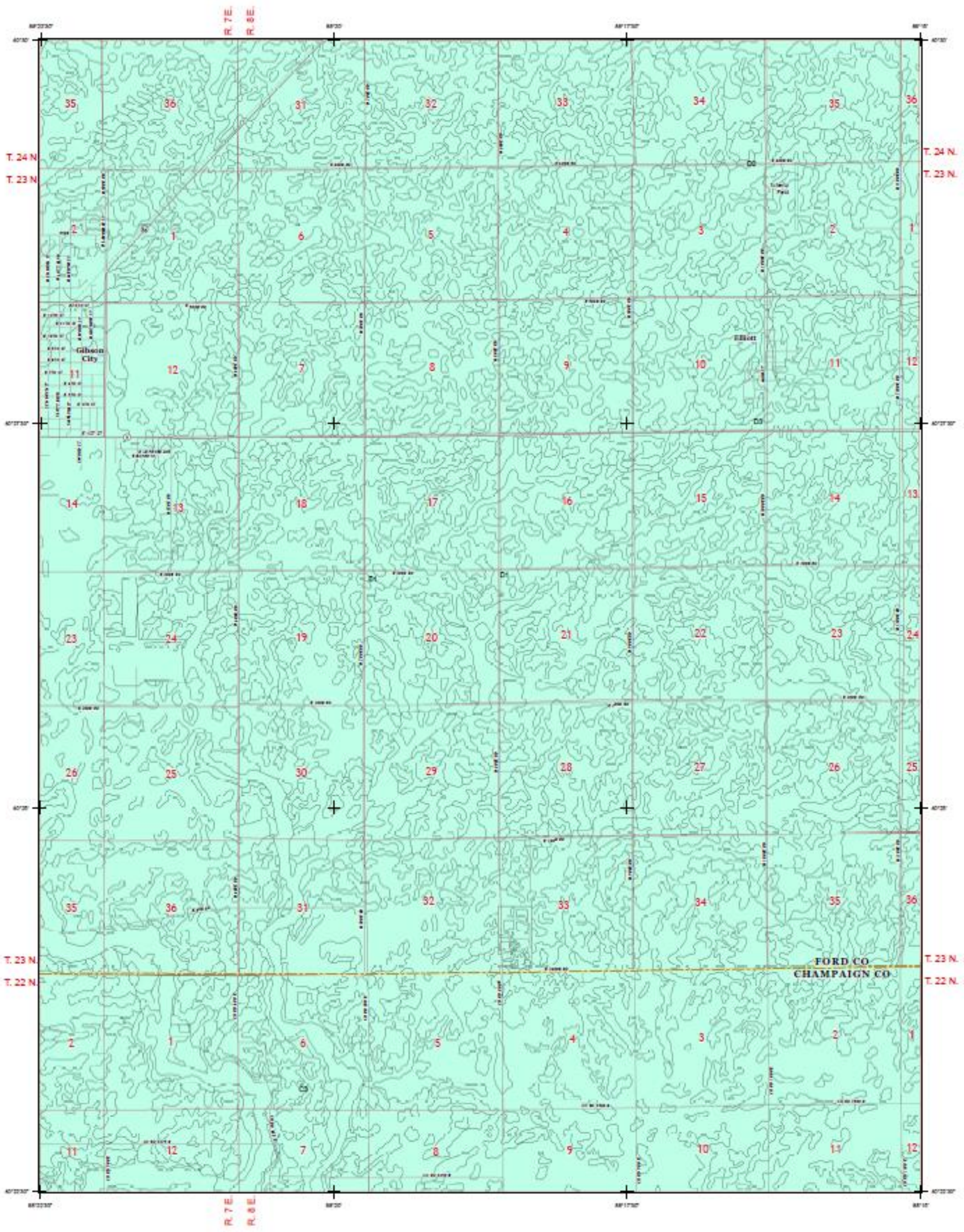


Figure 6: Distribution of USDA-NRCS soil data (USDA, 2017) prior to classification of polygons

Table 1: Example of soil codes (MUSYM) matched with corresponding parent material from the USDA-NRCS Custom Soil Report.

MUSYM	USDA Soil Parent Material	Lithology
189A	Lacustrine deposits	Glacial lake sediment
148B	Loess over stratified loamy outwash	Glacial outwash
146A	Thin mantle of loess over silty clay loam till	Till
375B	Loess and in the underlying till or lacustrine deposits	Till/Glacial lake sediment
67A	Calcareous loess and/or glacial drift	Till
134A	Loess over loamy outwash	Glacial outwash
238A	Colluvium	Glacial outwash
3107A	Alluvium	Alluvium

Geologic and geophysical logs recorded during the drilling of water wells, highway and bridge borings, oil and gas exploration borings, and coal structure test borings were obtained from the Illinois State Geological Survey (ISGS) to further verify the material thicknesses and extent of the parent materials. Within the Quadrangle there are 206 boreholes with information (of varying quality) about the subsurface geology. Geologic logs from nine (9) highway projects in Ford County and 10 projects in Champaign County were also examined. As part of the mapping process, the water well boreholes were located more accurately using tax parcel data or verified in the field. Water well locations had to be verified as the locations are displayed by default at the center of the ¼ - ¼ - ¼ - section on the ISGS ILWATER website.

After verifying the thickness and extent of the various parent materials, they were then classified to lithostratigraphic units using the frameworks developed by Willman et al. (1975) and Hansel and Johnson (1996). In some instances, the parent material could not be directly translated to a lithostratigraphic unit based solely on its lithologic description. An example of this is the Ashkum silty clay loam (MUSYM = 232A), which was found in both the southwestern corner of the Quadrangle south of the moraine as well as in the moraine complex. Based on the lithologic description of the parent material, the Yorkville Member would be the most direct translation for the Ashkum silty clay loam, however, Johnson et al. (1971) classified the Batestown Member as the till south of the Illiana Morainic System and the Yorkville Member as the younger, coarser grained till immediately to the northeast and overlying the Batestown Member. Therefore, it does not make sense to classify every polygon containing the Ashkum loam as the Yorkville Member. In these instances, LiDAR data were useful for mapping the geomorphic landforms which could be used to assist in differentiating lithostratigraphic units.

LiDAR elevation data were obtained from the ISGS as a raster dataset in the form of a Digital Terrain Model (DTM) and derivative hillshaded georectified image. The LiDAR model was used to identify the boundaries of floodplains, fans, moraines, glacial lake basins, and partially buried esker-type ridges. The Illiana Morainic System which could be identified using the LiDAR served as a distinguishing feature between the two till units within the Quadrangle. To assist with defining the extent of fan deposits, two-foot contours were generated from the DTM. Having contours at this topographic scale allowed me to identify the subtle differences in elevation. Small depressions or bowl like features have been interpreted as kettles or lakes (cf. Grimley et al, 2016), while narrow linear ridges that are partially buried could be eskers, or some other type of subglacial landform formed by water (cf. Evans et al., 2009; Grimley et al., 2017).

The last step in developing the map included field verification of the geologic (map) units. This step proved difficult as there were no large outcrops or natural exposures within the Quadrangle. During the time of field verification, several fields were being excavated for the placement of tile drains. The trenching allowed me to visually identify the surficial material at three different locations (see Appendix C).

Following the fieldwork, polygons were created and digitized in ArcMap to represent the various lithostratigraphic units. The polygons were then saved as individual layer files in ArcMap, and then imported into a topographic style template, provided by the USGS (https://viewer.nationalmap.gov/tools/topotemplate/). This map style template included individual layers representing features such as elevation contours, roads and highways and water bodies.

Aquifer Sensitivity

Aquifer sensitivity within Gibson City East Quadrangle was determined from the surficial geology map and borehole database following the methodology described by Berg (2001). Aquifer sensitivity is based on the depth to the shallowest aquifer unit, and its relative thickness. Subsequent studies in the glaciated upper US Midwest by Klaseus et al. (1989) in Minnesota and Libra et al. (1993) in Iowa highlighted the importance of depth to aquifer unit and reported a very low occurrence of contamination of agrichemicals in groundwater below ~115 feet (35 m) depth. Aquifer thickness is also assessed in this classification system. Thicker aquifer units are generally considered to contain more valuable groundwater resources than thinner aquifers, and thus are deemed more sensitive. Section 620.210 of the Illinois Amendments to Groundwater Quality Standards (35 Ill. Admin. Code § 620) was used by Berg (2001) to specifically define what constitutes an aquifer in the classification system. The Code states that a potable groundwater resource can be found in a porous coarse-grained sand and gravel aquifer greater than 5 feet thick. For this analysis, ranges in hydraulic conductivity are assumed for various geologic materials (Table 2).

Table 2: Estimated hydraulic conductivity of typical geologic materials in east-central Illinois (modified from Berg, 2001). Aquifer materials are shaded in green and aquitard materials are shaded in red.

Geologic materials	**Hydraulic conductivity (cm/sec)**	**Comments**
Coarse sand and gravel, well sorted	1×10^{-3}	May be highly permeable; good aquifer material
Fine sand and silty sand	1×10^{-5} to 1×10^{-3}	Good aquifer material
Silty to clayey glacial sediments	1×10^{-9} to 1×10^{-5}	Includes till and lacustrine sediment; commonly contain gravel/sand lenses; generally non-aquifer material
Silt and fine sand	1×10^{-6} to 1×10^{-4}	Loess; non-aquifer material; surficial unit

Berg (2001) divides the subsurface into five depth ranges: 0 to 5 feet (0 – ~1.5 meters), 5 to 20 feet (~1.5 - ~6.1 meters), 20 to 50 feet (~6.1 – 15.2 meters), 50 to 100 feet (~15.2 - ~30.5 meters), and greater than 100 feet (~30.5 meters). Aquifer thickness is recorded in three groups: less than 20 feet (~6.1 meters), 20 to 50 feet (~6.1 – ~15.2 meters), and greater than 50 feet (~15.2 meters). An aquifer sensitivity classification is assigned based on which set of metrics for depth and thickness best describe the aquifer of interest (e.g., an aquifer within five feet of the land surface and greater than 50 feet thick would be assigned the classification of A1, or most sensitive). Table 3 shows the complete classification system for assigning the aquifer sensitivity.

The first step in completing the aquifer sensitivity analysis involved further analyzing borehole geologic logs to determine the depth to the first aquifer at each location, the thickness of that aquifer unit, and properties of the aquifer materials. When analyzing the logs, the first sand and gravel unit encountered from the land surface at least five feet thick is considered the aquifer used in the analysis. Aquifer units meeting this requirement but found to be partially dewatered were also considered because they can still provide a hydraulic pathway for the flow of groundwater (cf. Dey et al, 2007).

Table 3: The classification system for aquifer sensitivity (From Berg, 2001). Five primary map categories are differentiated (A-E), with A representing materials with the highest sensitivity and E with the lowest. The categories are further subdivided into more detailed units. It should be noted in Berg (2001), aquifers in sand and gravel and high permeability bedrock are classified together, but in the study area, the bedrock is not within 100 feet of the land surface.

Sensitivity Class	**Description**
A3	Sand and gravel or high-permeability bedrock 20 to 50 feet thick within 5 feet of the land surface.
A4	Sand and gravel or high-permeability bedrock 20 to 50 feet thick between 5 and 20 feet below the land surface.
B1	Sand and gravel or high-permeability bedrock between 5 and 20 feet thick within 5 feet of the land surface.
B2	Sand and gravel or high-permeability bedrock between 5 and 20 feet thick between 5 and 20 feet below the land surface
C2	Sand and gravel or high-permeability bedrock between 20 and 50 feet thick between 20 and 50 feet below the land surface
C3	Sand and gravel or high-permeability bedrock <20 feet thick between 20 and 50 feet below the land surface
D2	Sand and gravel or high-permeability bedrock between 20 and 50 feet thick between 50 and 100 feet below the land surface
D3	Sand and gravel or high-permeability bedrock <20 feet thick between 50 and 100 feet below the land surface
E1	Sand and gravel or high-permeability bedrock not present within 100 feet of the land surface.

Using Microsoft Excel™ software, a spreadsheet with the depth to the first aquifer unit, thickness of the unit, and type of aquifer material was compiled. Then a logical formula using “IF” statements was computed to assign an aquifer sensitivity classification value to each borehole. An additional formula was then written to convert the alphanumeric aquifer sensitivity classifications into numeric classifications (i.e., A1 = 1, A2 = 2, etc.) in order that an interpolation analysis could performed later using ArcGIS software. The Excel data file was then joined to the attribute table of locational information in ArcMap so the sensitivity classifications could be viewed spatially in the study area.

Because of the limited number of boreholes and lack of associated geophysical data, which would allow for a more accurate characterization of geologic materials, an Inverse Distance Weighted (IDW) interpolation was performed to interpolate sensitivity ratings between boreholes (Figure 7). IDW was chosen over other interpolation methods because the IDW algorithm assumes that the variable being mapped decreases in influence with distance from its sampled location (ESRI, 2016). Therefore, the measured values closest to the prediction location have more influence on the predicted value than those farther away. My assumption was that the geology at a given location is more likely to be consistent with the nearest borehole than material further away. It is understood that the interpolation did not consider other parameters such as the geomorphology and subsurface heterogeneities mapped in adjacent areas when making interpolations between boreholes. Therefore, the IDW results serve as an initial analysis which helps to begin to define sensitivity boundaries. Results of the IDW analysis were overlain over the surficial geologic map to assist in refining the boundaries of the sensitivity classes. The IDW was referenced when sensitivities varied within the same geologic unit. The IDW results were utilized for defining the boundary between the E1 and D3 regions within the moraine complex, as well as determining the extent of some of the small sand and gravel lenses found throughout the Quadrangle. In several areas on the map, the IDW produced “bull’s-eye” shapes around lone boreholes where the aquifer sensitivity varied from the surrounding classifications (e.g. Section 35, T23N, R8E). These regions may represent heterogeneities in the aquifer units or could be a result of suspect data. The surficial geology was referenced in these regions to try and more accurately define the extent of the areas represented by the singular data points. If no surface features were present, these “bull’s-eye” regions were left off the final renderings of the aquifer sensitivity map and the data point was incorporated with the surrounding sensitivity class.

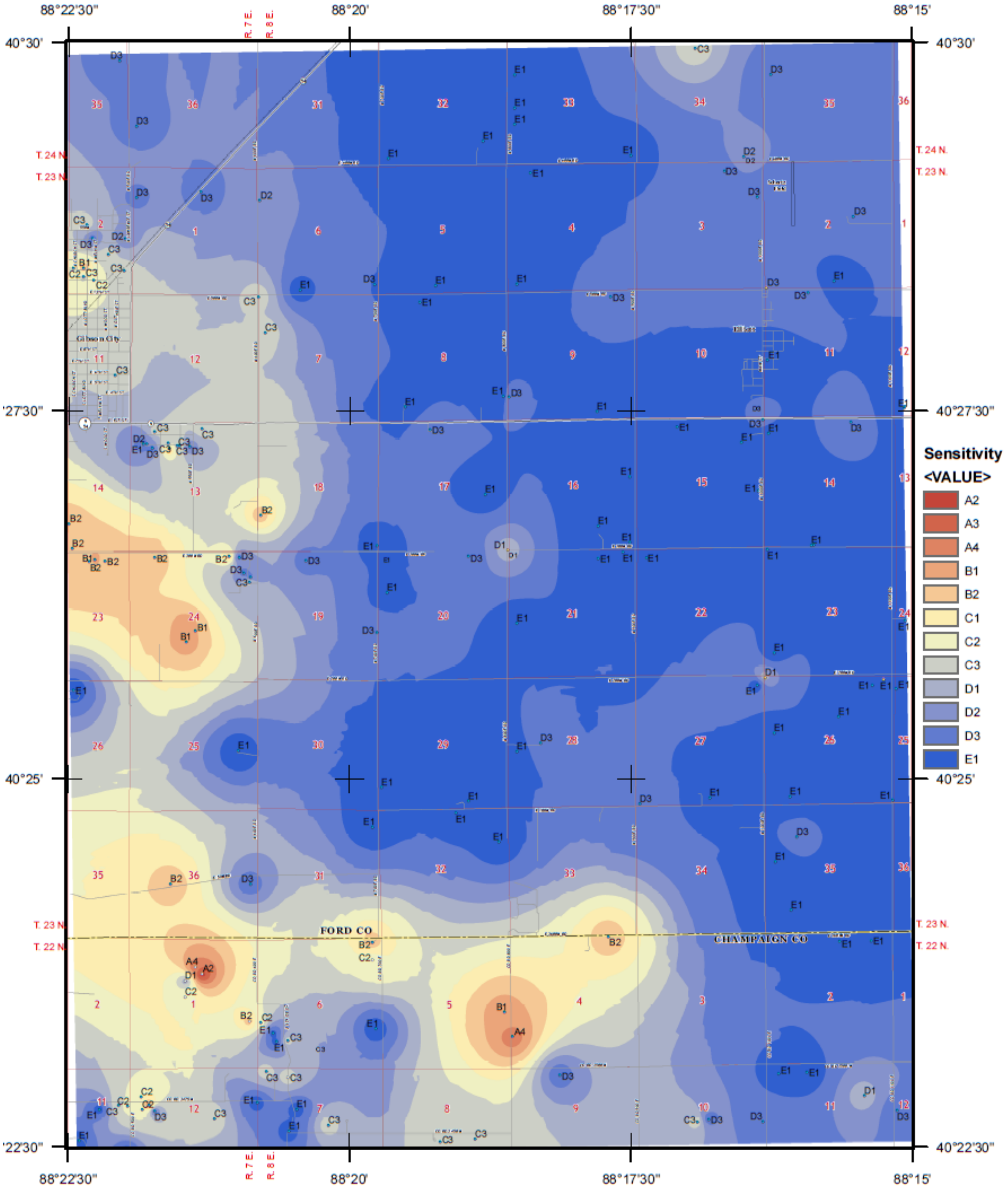


Figure 7: Inverse Distance Weighted interpolation analysis of the aquifer sensitivity classes within the Gibson City East Quadrangle.

CHAPTER III: RESULTS

Surficial Geology

The interpreted parent materials map revealed five lithologies within the Gibson City Quadrangle: sand, silt, clay, and gravel; silt and clay; sand and gravel; diamicton; and a mix of diamicton and silt and clay (Figure 8). These deposits were translated into five lithostratigraphic units represented on the Surficial Geologic map (Plate 1). The units, from youngest to oldest, are as follows: the Cahokia Formation, Equality Formation, the Batavia Member of the Henry Formation, and the Yorkville and Batestown Members of the Lemont Formation. The following section provides a detailed description of the how the units were assigned based upon the lithology and the geomorphic features within the Gibson City East Quadrangle.

Within the Quadrangle, the Cahokia Formation was found to be up to 15 feet thick and was identified in the floodplains and channels of the Sangamon River, Drummer Creek, Dickerson Slough, Blackford Slough, as well as several other small, unnamed streams. The LiDAR hillshade proved very useful for identifying these channels and floodplains (Figure 9). The Cahokia Formation is also found in fan-shaped deposits that emanate from the valleys of the moraine, where the topography flattens out to south of the Illiana Morainic System. In these areas, the alluvium onlaps with glacial outwash. Only five boreholes penetrated the fan deposits. Therefore, defining the extent of the alluvial deposits was guided by the configuration of 2-foot contours derived from the LiDAR DEM. Drilling into these deposits generally encountered thin deposits of fine-grained sediment (silt and clay) in the valleys of the moraine with thicker, coarser deposits (sand and gravel mixed with clay) in the fans.

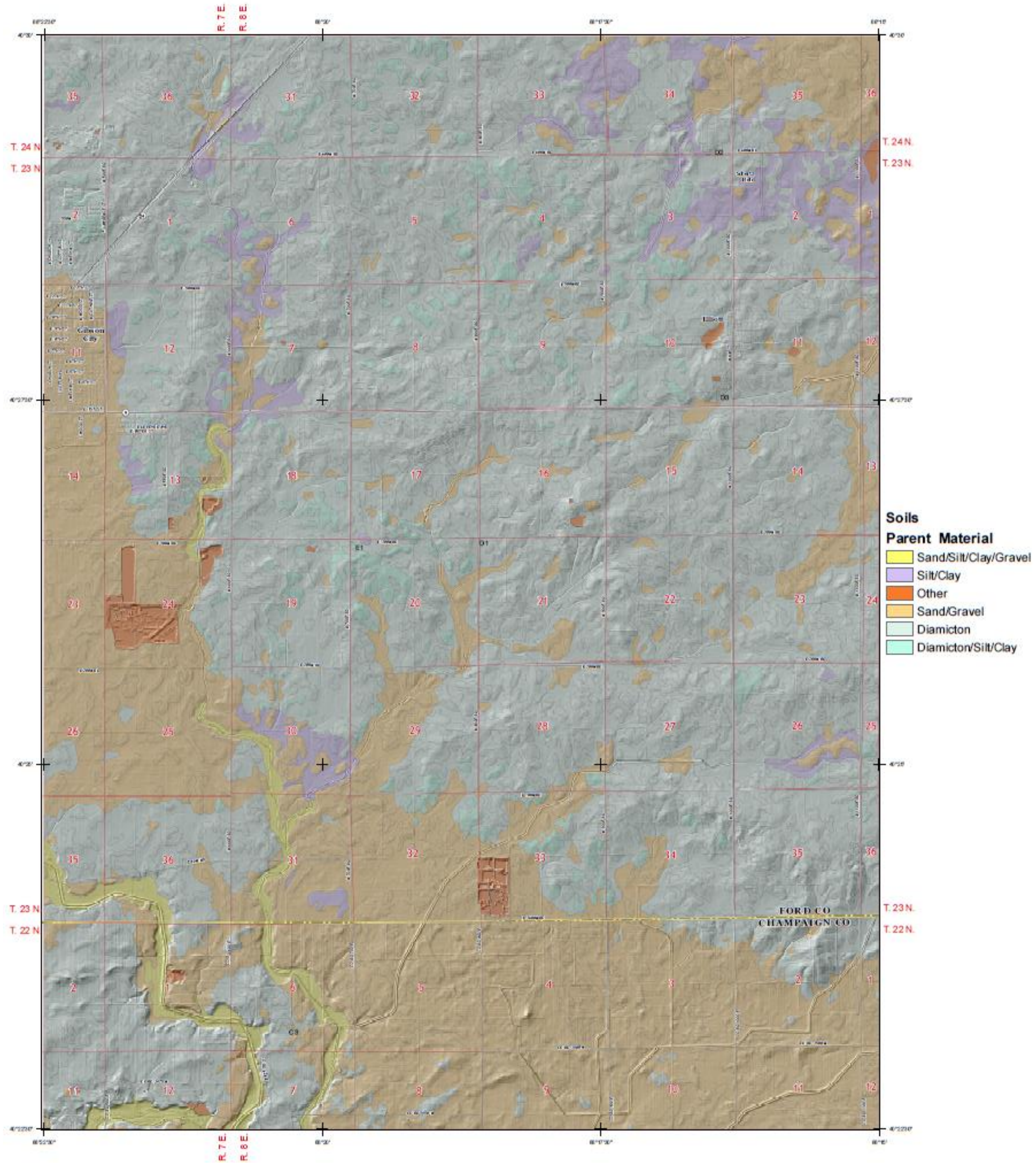


Figure 8: Interpreted parent materials of the soils in the Gibson City East 7.5-Minute Quadrangle (Other indicates water bodies and earthy fill) (soils data from USDA, 2017).

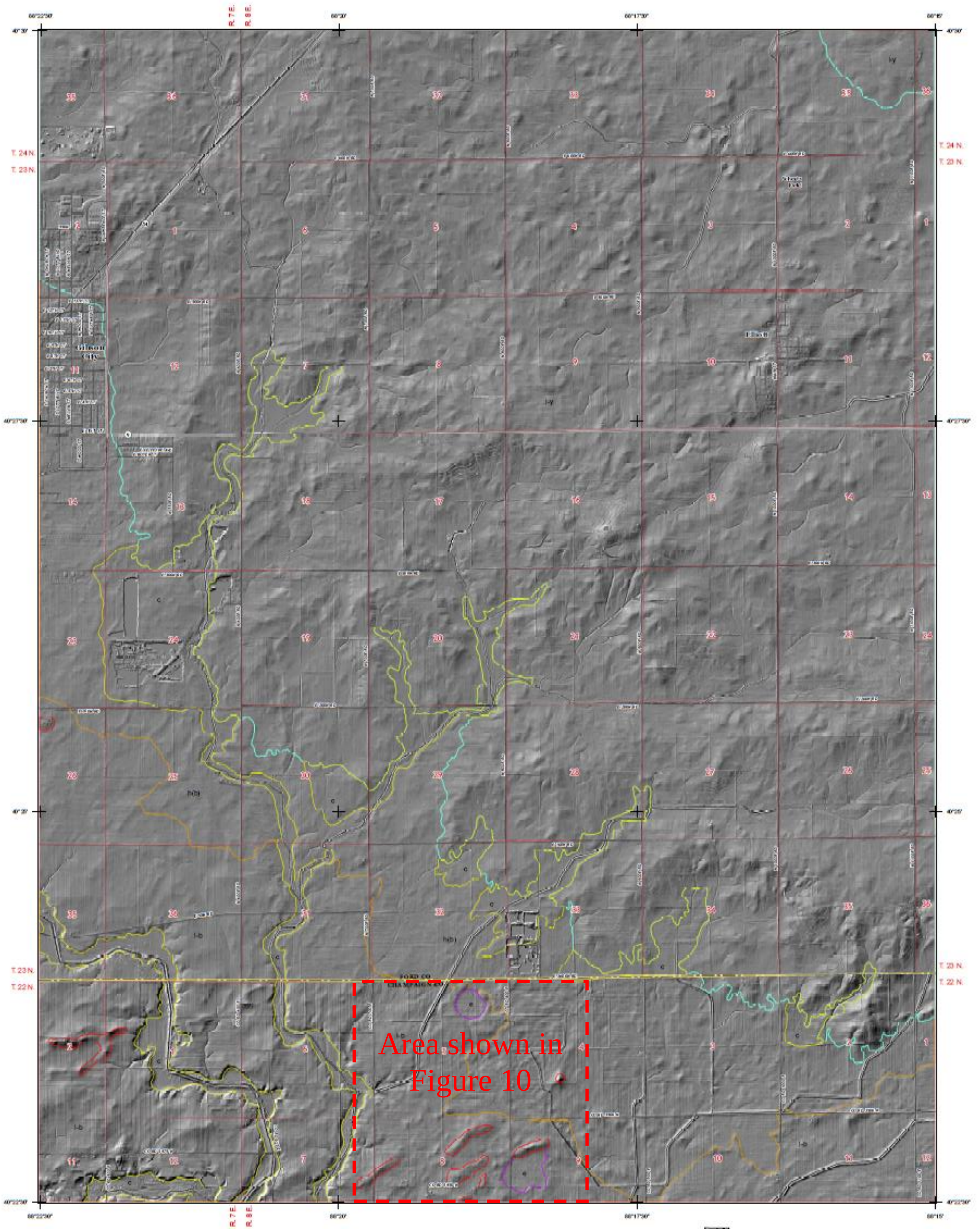


Figure 9: LiDAR hillshaded DEM depicting the following geomorphologic features within the Gibson City East Quadrangle: morainic system outlined in blue (and yellow where the boundary is shared with alluvium), flood plains/river channels outlined in yellow, outwash plain outlined in brown, glacial lake plains outlined in purple, and esker/kame-type features in red.

The Equality Formation was interpreted to be in two locations in the south-central region of the Quadrangle. The two areas identified as lacustrine within the Quadrangle were identified based on bowl shaped depressions seen in the LiDAR (Figure 10). Soil data classified the parent material as outwash, and well data were unavailable at either of these locations to confirm the units. Further field analysis including a soil boring should be completed to confirm the lithology of these deposits.

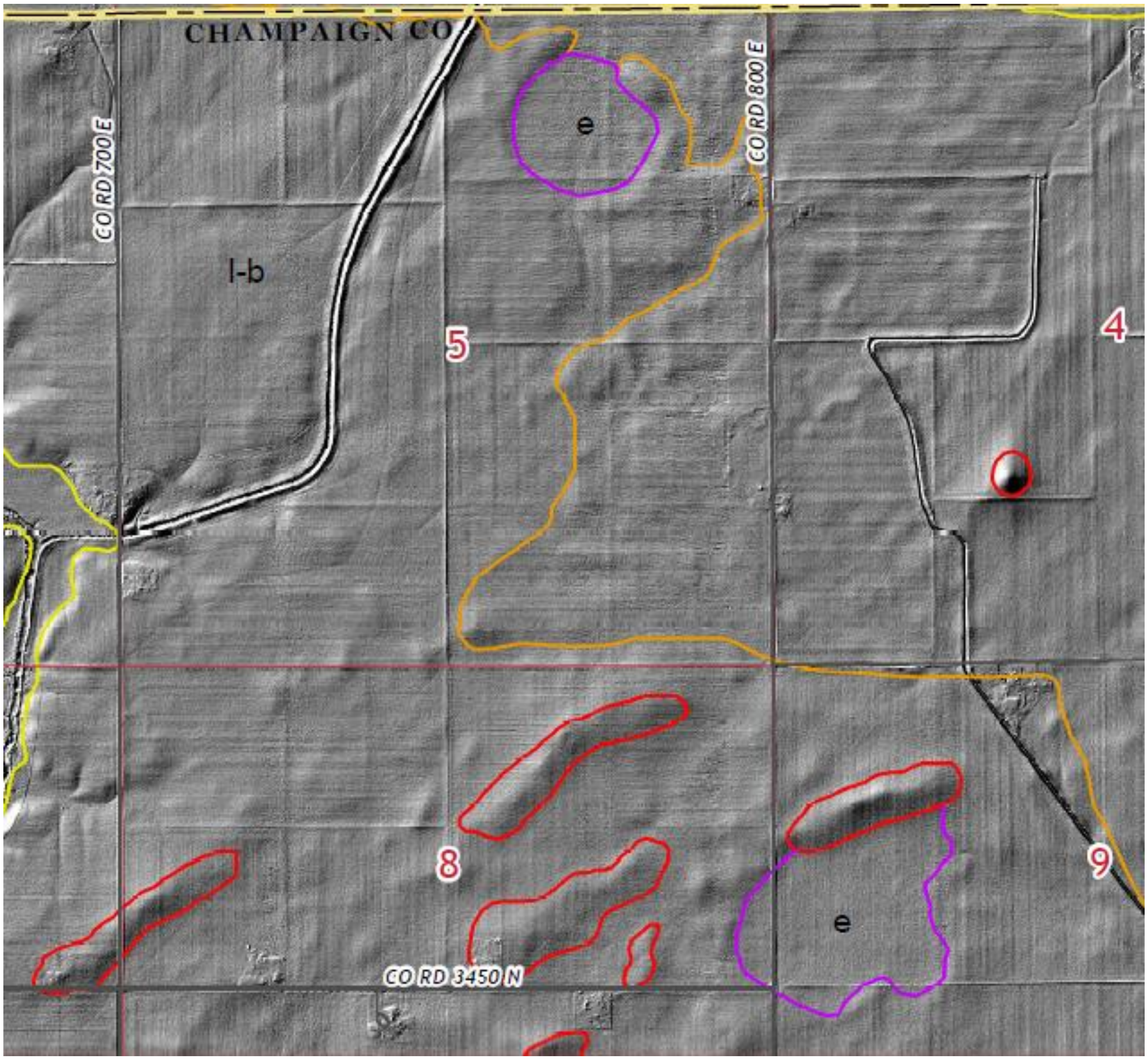


Figure 10: LiDAR hillshaded DEM outlined in Figure 9 resembling the following geomorphologic features within the Gibson City East Quadrangle: glacial lake plains outlined in purple, outwash plain outlined in brown, and esker-type ridges/kame-like features outlined in red.

The informally named Batavia Member of the Henry Formation was found to be up to 17 feet thick within the Quadrangle and was deposited along the front of the Illiana Morainic System, converging into the valleys. The Batavia Member deposit trends from southeast to northwest, forming a natural division between the two till units found within the Quadrangle. Borehole logs in Section 14 (T23N, R7E) and Sections 4 and 5 (T22N, R8E) generally showed coarser deposits of sand and gravel, while the deposits in the remaining portions of the Batavia Member showed finer deposits of silty sand and sand (Plate 1).

The informally named Wasco Member of the Henry Formation comprises sand and gravel found in eskers and kames. Wasco Member deposits were not identified on the surficial geologic map as no borings are available to confirm their sedimentology; however, deposits bearing slight resemblance to these features are present in the south and southeastern region of the Quadrangle (Figure 10).

Two Members of the Lemont Formation were identified in the Gibson City East Quadrangle, the Yorkville and Batestown. The Yorkville Member was found to be up to 27 feet thick and is the dominant surficial unit in the Quadrangle, with the extent indicated by the Illiana Morainic System. The Yorkville Member polygon in the northeast corner of the map which does not contain the speckled pattern represents ground moraine deposits as opposed to the deposits found within the moraine system.

The final unit found in the Quadrangle, the Batestown Member, was found to be up to 65 feet thick in the Quadrangle and is located in the southwest and southeast corners of the study area, south of the Illiana Morainic System. The surface topography is hummocky in these areas. The Batestown comprises ground moraine deposits, signifying the retreat of glacial ice.

Aquifer Sensitivity

The aquifer sensitivity analysis identified 9 sensitivity classes for potential contamination in the Gibson City East Quadrangle ranging from highest sensitivity (A3) to lowest sensitivity (E1) (Plate 2).

The lowest values for aquifer sensitivity, E1, are predominantly located in the area of the Yorkville Member, on the apex of moraines within the Illiana Morainic System. This area represents the thickest succession of glacial deposits within the Gibson City East Quadrangle, where aquifer material is not present within 100 feet of the land surface. Smaller areas mapped as E1 are scattered throughout the southern portion of the Quadrangle. These areas represent the absence of aquifer material in the boreholes indicating regions where small, local aquifers pinch out.

The D2-3 sensitivity classes are also found primarily within the boundaries of the Illiana Morainic System; however, these values tend to be located directly north or south of the apex of the moraine. The D sensitivity class represents aquifer material that is found between 50 and 100 feet of the land surface. The location of these classes shows the gradual thinning of confining sediments as we move away from the apex of the moraine.

Intermediate values for aquifer sensitivity, C2-3, were found primarily in the northwest lobe of the Illiana Morainic System and to the southwest where the Batestown Member is present. Aquifer sensitivity classes in the C range represent aquifer material that is present between 20 and 50 feet below the land surface. It is possible there is less till overlying the aquifers in the northwest lobe of the moraine as later meltwater may have washed away some of the overlying sediment. The location of wells is somewhat randomly spaced in the southwest region of the Quadrangle, in the area that contains the Batestown Member. Additionally, the sensitivity values assigned based upon the well data varied greatly in this area (Figure 7). The random distribution of the wells and wide variance in sensitivity classifications made interpretations in this region difficult. The C3 classification was designated the default value in southwest region of the map where a lack of data was present. This classification was the most common class assigned to wells in this area, and a general assumption was made that the subsurface geology in this region is somewhat consistent. It should be expected that an intermediate sensitivity value, e.g. the C class, would belong in the area south of the moraine terminus, where there is less till. In general, this study tended to error on the side of assigning higher sensitivity values. Relatively small areas of the C2 were also found in the southwest corner of the map. The C2 class represents areas where the aquifers are thicker (20-50 feet thick).

The B1 and B2 sensitivity classes were primarily assigned to the Batavia Member of the Henry Formation and to the Cahokia Formation. The B classification is defined as sand and gravel between five and 20 feet thick. The B1 classification, which contains aquifers within five feet of the land surface, was assigned to the regions of the Henry Formation that contained coarser sand and gravel deposits (Section 14, T23N, R7E and Sections 4 and 5 of T22N, R8E). The B2 classification, which contains slightly deeper aquifer material between five and 20 feet below the land surface, was assigned to the remaining portions of the Batavia Member where the surficial outwash deposits are finer grained containing silty sand and sand. The B2 classification was also assigned to the deposits of the Cahokia Formation, because the boreholes within the Cahokia generally contained finer grained surficial deposits in the first ~5 feet of the borehole log, with coarser sand and gravel deposits present between five and 20 feet below the land surface.

The highest values for aquifer sensitivity, A3 and A4, were found south of the Illiana Morainic System. Only four borehole logs depicted aquifer units that could be interpreted to the A classifications, representing small lenses of thicker aquifer material found between five and 20 feet below the land surface. Two of the four boreholes classified as A were petroleum wells (Section 1, T22N, R7E). The surficial data provided with these logs may be suspect as the sensitivity classifications were outliers in the area and petroleum loggers tend to speed through unconsolidated materials, lumping units together and providing limited descriptions of the materials. Investigation into these areas including a geophysical investigation would help to verify and more accurately define the boundaries of these highly sensitive areas. Two former gravel pits that are now ponds (Section 24, T23N, R7E and Section 33, T23N, R8E) were assigned to the A3 classification because they may have exposed deep aquifers to the surface. Additional investigations into the connectivity of these units would also be beneficial.

In general, the northern half of the Gibson City East Quadrangle where the surficial deposits are comprised of the Yorkville Member is assigned a low aquifer sensitivity to contamination. Areas with surficial deposits of the Henry and Cahokia Formations exhibit higher sensitivities. A large portion of the higher sensitivity surficial aquifers overly the Mahomet Aquifer in the southern portion of the Quadrangle. Fortunately, there are no known recharge areas for the Mahomet Aquifer within the Gibson City East Quadrangle. To confirm this assumption, an additional investigation into the wells that draw form the Mahomet Aquifer was conducted. The stratigraphy of the sediments logged in the wells believed to be drawing from the Mahomet Aquifer was assessed to determine if there may be potential stacked sand and gravel layers that might permit recharge. No such stacked sequences were observed (Figure 10). This conclusion is confirmed by Hackley et al. (2010), who sampled a well in the study area and found the groundwater had low $^{14}C_{DIC}$ activity (28.1 pMC), indicating there is likely no recharge.

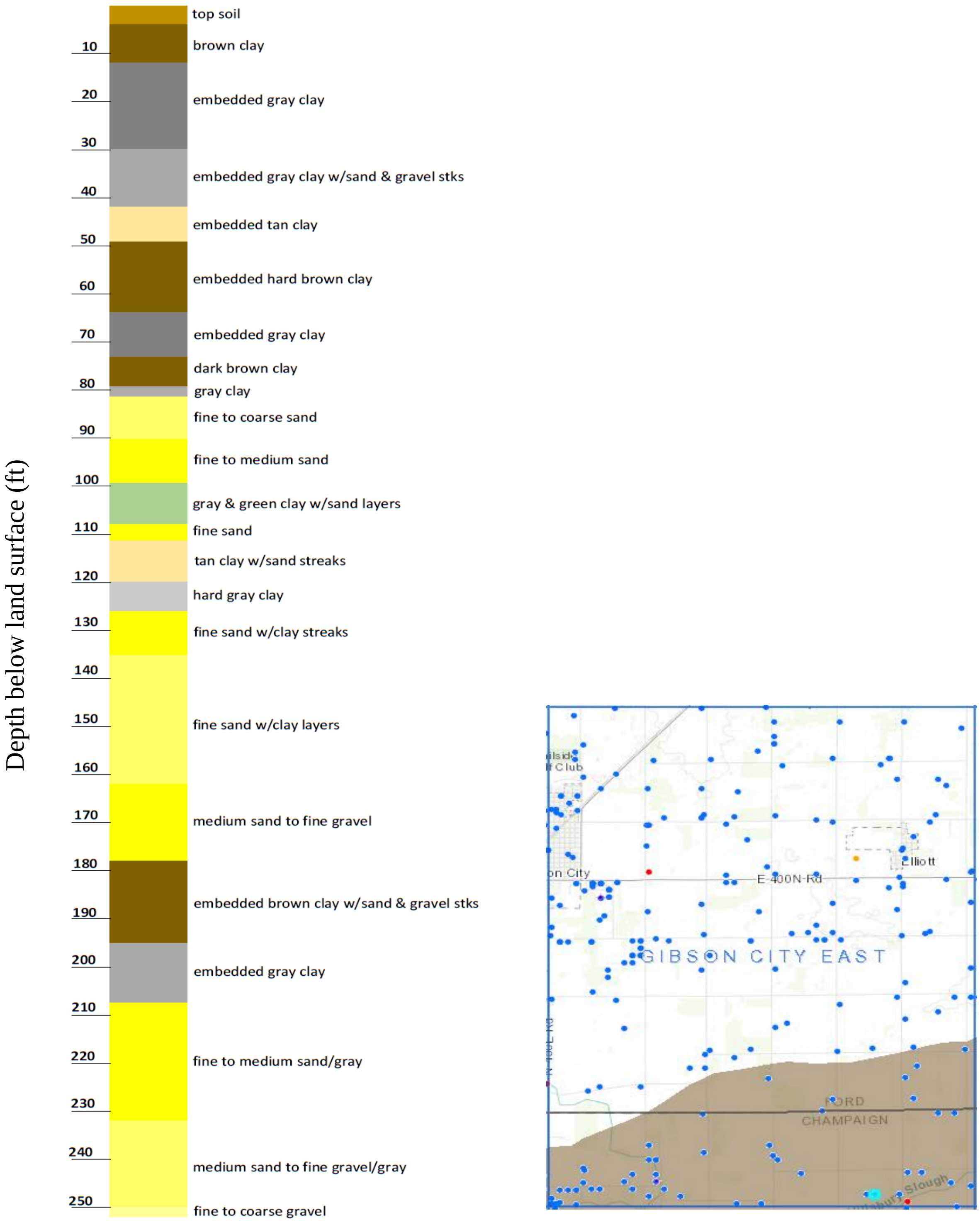


Figure 11: Well log (API #120192451700) showing the various thicknesses of till and sand and gravel layers. Location of the well is indicated by the bright blue dot in the bottom right. Shaded brown area within the location map represents the boundary of the Mahomet Aquifer (from ILWATER).

CHAPTER IV: DISCUSSION

Surficial Geology

Surficial geologic mapping helped to provide a better understanding of the distribution of glacial and postglacial deposits within the Gibson City East 7.5-Minute Quadrangle. This section will provide further insights into how the various lithostratigraphic units found within the Quadrangle tell the story of the geomorphic history of the area.

The youngest of the Wisconsin Episode deposits is the Equality Formation. The Equality Formation represents two areas in the Quadrangle where glacial lakes were once present. The water that filled these lakes was derived from glacial meltwater; however, there are two possible interpretations of how these lakes formed. The first is that these lakes are kettle lakes that formed when ice blocks broke off from the retreating ice during the end of Putnam Phase of the Michigan Subepisode. The second interpretation is that these lakes are a result of younger meltwater from the Livingston Phase of the Michigan Subepisode filling in depressions in the topography created by the erosion of the Batestown Member. Boreholes could help to verify that these are in fact lake deposits and not just depressions in the land surface, as the presence of varves would confirm the lacustrine nature of these features. While either interpretation for how these lake deposits formed might show varves in a boring, slumping around the lake might confirm that these are kettles because as the ice block melted the surrounding sediment may lose some of its stability allowing for slumping to occur. Additionally, kettle lakes in other regions such as the Tetons are typically more circular and pothole shaped, therefore, the northern lake identified on the surficial map is more likely to be a kettle than the southern lake.

The Batavia Member of the Henry Formation contains outwash deposits representing the retreat of the Livingston Phase ice. The coarser sand and gravel outwash deposits found in

Section 14 (T23N, R7E) and Sections 4 and 5 (T22N, R8E) represent areas where the glacial meltwater was flowing faster, allowing it to carry these larger sediments. These areas may indicate where the primary channels of a braided stream system existed coming from the moraine. The remaining areas of the Batavia Member contain finer grained deposits, likely representing regions where meltwater was flowing more slowly.

The Yorkville Member which comprises the Illiana Morainic System represents the maximum extent of the advancement of the Livingston ice, and is the result of a period in which accumulation was roughly equal to ablation allowing the ice to remain stagnant for an extended period of time and permitting the continuous deposition of unsorted sediment at the glacial margin. Additionally, the northwest to southeast trend of the moraine complex indicates the ice was flowing from the northeast.

The Batestown Member is a result of a more significant advance of the Decatur Sublobe during the Putnam Phase, which extended further south beyond the confines of the Quadrangle. The lack of a moraine in the southern portion of the Quadrangle signifies a relatively constant retreat of the ice. The hummocky features that trend from northeast to southwest in the south-central portion of the Quadrangle help to determine the direction of flow of meltwater, if there was any. These features were described as possibly being Wasco Member eskers and kames in the results section; however, since the sedimentology of these deposits could not be confirmed, the features are interpreted to be the result of meltwater eroding the till of the Batestown Member.

Aquifer Sensitivity

The Aquifer Sensitivity map of the Gibson City East Quadrangle helped to establish a base work for the hydrogeology and contamination potential of the study area. This analysis may provide insight into the subsurface hydrogeology and flow patterns.

The E and D classifications represent areas where thick sequences of silty to clayey diamicton at the land surface prevent rapid infiltration. These classifications which are present primarily in the moraine complex, represent an area where aquifer material is not present within 50 feet of the land surface. Because the thickest sequence of Yorkville Member diamicton was only observed to be 27 feet thick, this indicates that as the Livingston ice advanced it likely eroded away any older outwash deposits, which could have comprised local aquifers, left by the retreating Putnam Phase. While infiltration and aquifer sensitivity are low in the area of the moraine, increased surface runoff may occur due to the steeper slopes from the moraine complex, especially in the winter months when fields are fallow. Surface runoff on the south side of the moraine may make its way to the Cahokia and Henry Formations at the base of the moraine, meaning some surface water on the moraine could end up recharging the upper most aquifer units connected to the Henry and Cahokia. Additionally, drain tiles within the diamicton are designed to route infiltrating water to the valley channels within the moraine, moving water from areas of low sensitivity to areas with relatively high sensitivity.

The A and B classifications represent areas where higher rates of infiltration are expected due to the coarser-grained sediments classified to the Henry and Cahokia Formations. The Henry and Cahokia Formations therefore likely characterize areas where the majority of recharge for the uppermost aquifer units occurs. Land owners or developers should exercise caution above these areas as contamination can more easily infiltrate these shallow aquifers. Additionally, if these lands are to be further developed, more refined studies such as geophysical investigations should be completed to more accuracy refine the extent of the sensitive aquifer materials.

As the findings of this study have shown, the methodology utilized for this analysis is useful for determining the sensitivity of the uppermost aquifer units, however, it is limited as it does not define the sensitivities of deeper aquifer units (more than 100 feet bgs) such as the Mahomet Aquifer. Several studies have indicated there may be localized connections between aquifer units which may allow for communication between the surface and the Mahomet Aquifer (Hackley et al, 2010; Roadcap et al, 2011; Stumpf and Dey, 2012) (Figure 11). While the uppermost aquifer units within the Gibson City East Quadrangle have highest sensitivities where underlying the Henry and Cahokia Formations, thick sequences of till classified to the Tiskilwa and Glasford Formations likely prevent direct recharge of the Mahomet Aquifer. To illustrate this concept, a cross section of the Mahomet Sand Member and overlying units is shown in Figure 12. The cross section was completed in Champaign County just south of the Gibson City East Quadrangle by Stumpf and Atkinson (2015). Generally in east-central Illinois, layers of coarse-grained sediments are either thin or not common in the diamicton units directly overlying the Mahomet Sand Member. Furthermore, the thick diamictons classified to the Tiskilwa and Glasford Formations prevent rapid infiltration from the land surface to the Mahomet Aquifer. These areas have a relatively low potential to transmit surface water to the Mahomet Aquifer. Additional 3-D geologic mapping in the study area, particularly where the Mahomet Aquifer is present would help to further revise the aquifer sensitivity analyses.

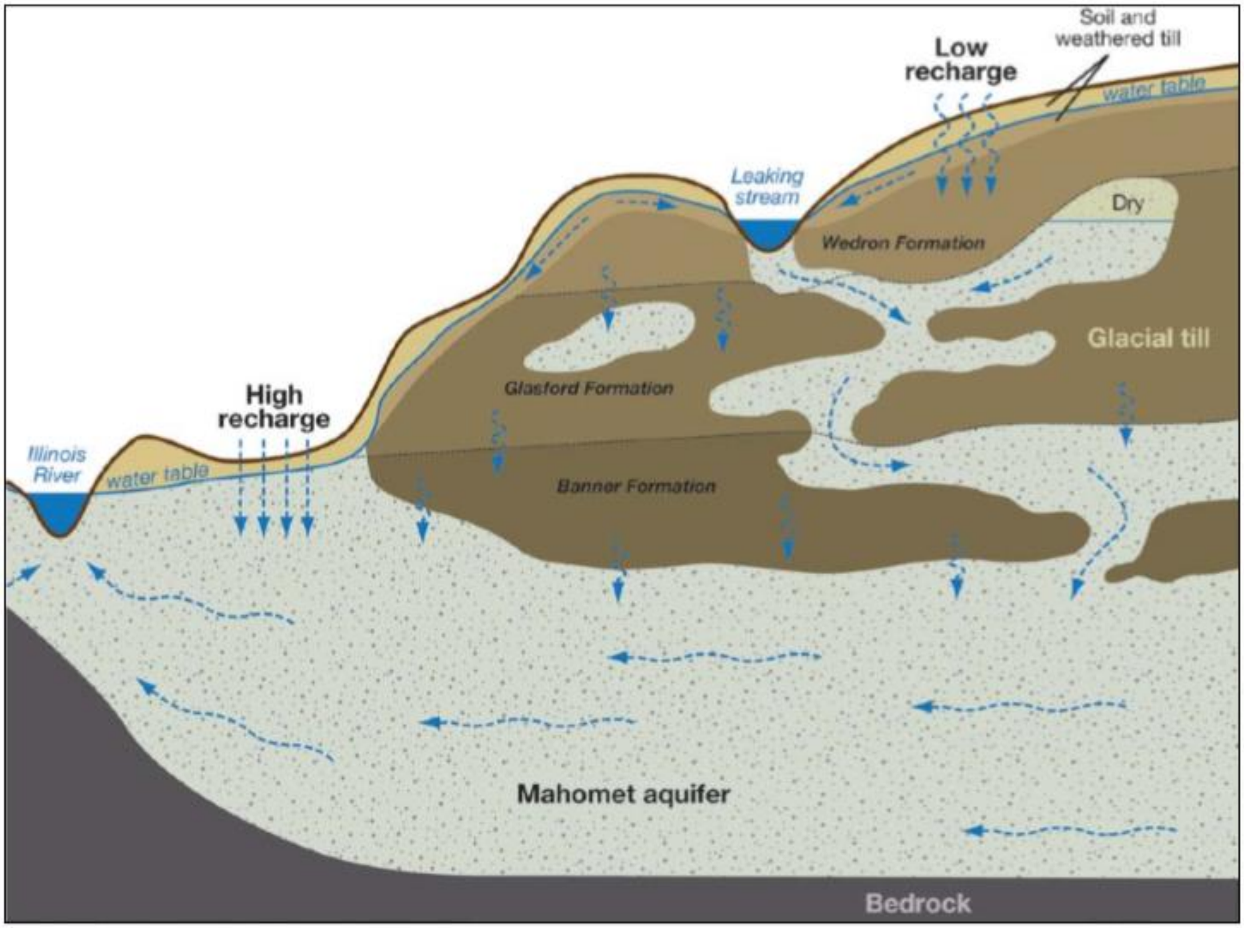


Figure 12: Conceptual model of flow in the Mahomet Aquifer (from Roadcap et al. 2011).

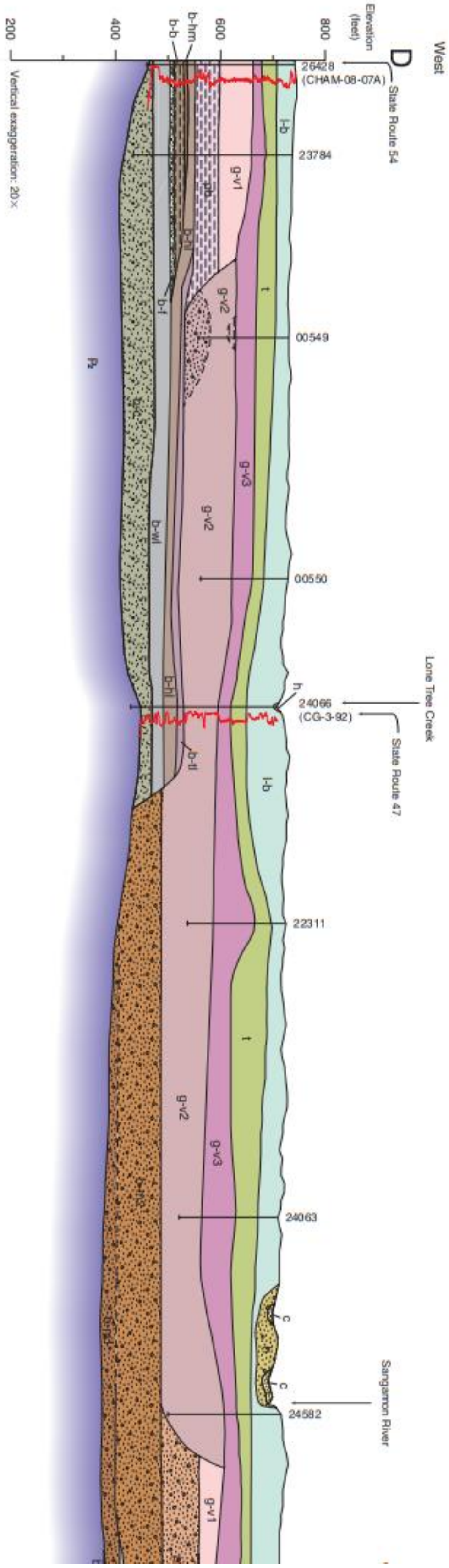


Figure 13: Cross section through the buried Mahomet Bedrock Valley (modified from Stumpf and Atkinson, 2015). The cross section pictured here does not show the full length of the transect from Stumpf and Atkinson (2015) but is cut shortly after crossing the Sangamon River. The location of the cross section can be seen in Figure 1 and unit descriptions in Figure 4.

CHAPTER V: CONCLUSIONS

This study was completed to provide a better understanding of the distribution of the surficial glacial and postglacial deposits within the Gibson City East Quadrangle, and to determine the sensitivity to contamination of the various shallow aquifers. With this information, water resource managers and planners could make more informed decisions on land use in an area that partially overlies the Mahomet Bedrock Valley.

The surficial geologic mapping identified five lithostratigraphic units that represent the glacial and postglacial events that occurred over the past ~24,000 years or so. The Illiana Morainic System, which trends from northwest to southeast is the prominent landform in the study area, which delineates the farthest extent of Yorkville ice into the study area. The use of LiDAR elevation topographic grids and hillshaded images allowed me to more accurately delineate boundaries of the geologic units that were reported in the county soil reports and borehole geologic logs.

The aquifer sensitivity analysis was conducted based upon information derived from the surficial geologic map. The 9 classes applied represent geologic materials having high to low sensitivity A3 to E1, respectively. In general, much of the study area has a low aquifer contamination potential, especially in the eastern region overlying the Illiana Morainic System. The thick sequences of silty to clayey till extending from the land surface to deep within the subsurface inhibits the direct infiltration into the underlying aquifer. Higher rates of infiltration are expected where sand and gravel of the Henry and Cahokia Formations are present at or just below the land surface.

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APPENDIX A: SURFICIAL GEOLOGIC MAP OF THE GIBSON CITY EAST 7.5-MINUTE QUADRANGLE

Plate 1

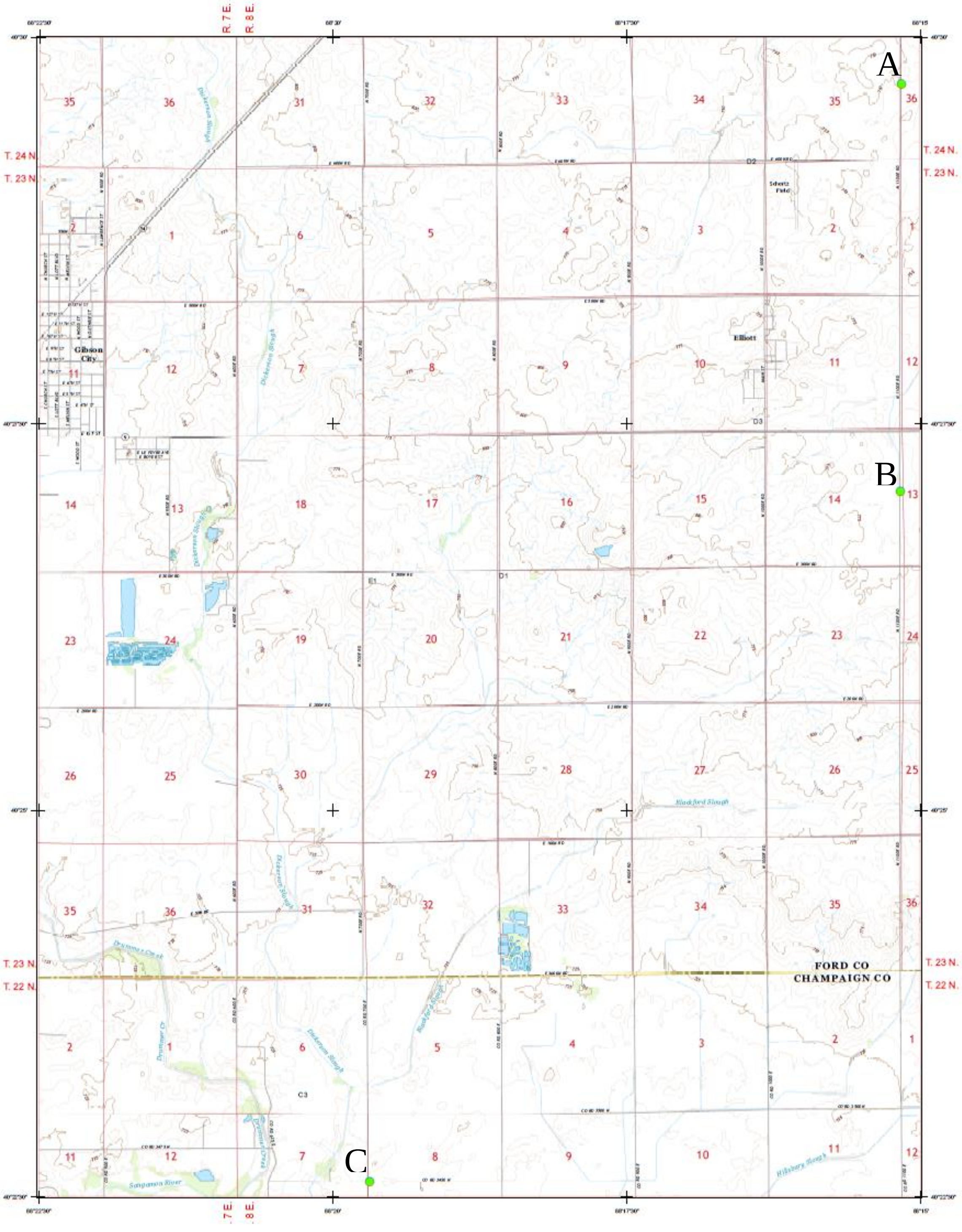
See back cover

APPENDIX B: AQUIFER SENSITIVITY OF THE GIBSON CITY EAST 7.5-MINUTE QUADRANGLE

Plate 2

See back cover

APPENDIX C: FIELD VERIFICATION



Site map showing the three locations (green dots labeled A, B,C) where sediment was observed from trenches dug for tile drains. Corresponding pictures seen on the following pages.

A. Diamicton observed in trenching at location (A).

B. Diamicton observed in trenching at location (B).

C. Diamicton observed in trenching at location (C).