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Stratigraphy and Extent of the Pearl-Ashmore Aquifer, Mchenry County, IL, USA

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Abstract Quaternary glacial till, outwash, lake sediments, and loess compose the surficial deposits of McHenry County, Illinois. Much of the landscape of McHenry County were formed by at least three separate advances of the Harvard Sublobe of the Wisconsin Episode Lake Michigan Lobe, which was part of the Laurentide Ice Sheet. This project focuses on the delineation of the stratigraphy and extent of the Pearl-Ashmore Aquifer. The Pearl-Ashmore Aquifer is the combination of the proglacial outwash of the Wisconsin Episode Ashmore Tongue of the Henry Formation and the youngest outwash associated with the Illinois Episode, which is the Pearl Formation. A 3-D geologic model was generated from a number of different subsurface geologic data sets, including geologic borings, and municipal and private water well records. These data were initially visualized and interpreted in the 3-D environment using ESRI's *ArcScene*. More than 700 wells were used to construct the model. The stratigraphic picks were imported into *Petrel, and* horizons were created from the surface data to complete the 3-D geologic model. Isopach maps of each unit were then created. The Pearl-Ashmore Aquifer extends through the eastern two-thirds of McHenry County. The 3-D geologic model predicts that the aquifer has an average thickness ranging from 5 to 15 m and is thickest in the north-central portion of McHenry County where it can reach thicknesses of up to 40 m.

Keywords: *Pearl-Ashmore Aquifer, McHenry County, IL, quaternary, Laurentide Ice Sheet, petrel*

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1. Introduction

McHenry County is one of the fastest growing counties in Illinois and the nation. Located northwest of Chicago, the communities within McHenry County have experienced a dramatic increase in both population and industry, which puts strain on the natural resources needed to sustain further development of the area. The Chicago metropolitan area experienced an 82% increase in urban building, a rate that is expected to be sustained for the next 20 years [1]. Because McHenry County is 100% dependent on groundwater for domestic, municipal, and industrial uses, additional resources will need to be delineated and developed Quaternary sand and gravel units have significant promise as aquifers. Quaternary aquifers have long been a major source (approximately 60%, deeper bedrock aquifers supply the balance) for both domestic and municipal water supplies in the County, but additional research needs to be done in order to insure their effective management and future productivity.

This project focuses on the delineation of the stratigraphy and extent of glacial sediments in north-central McHenry County, IL (Figure 1) with emphasis on a major local aquifer (Ashmore tongue, Henry Formation and Pearl Formation; herein called the Pearl-Ashmore Aquifer). Previous publications and maps indicate that the Pearl-Ashmore aquifer extends throughout the eastern two -thirds the county. This deposit extends longitudinally about 15 km is nearly 1 km across at its widest point, and ranges in thickness from 15-25 m. The Pearl-Ashmore Aquifer is used extensively by the city of Woodstock and other smaller communities in the area. However more additional research is needed in order to better understand this aquifer's characteristics, which will help with studies of local and regional aquifer systems.

Quaternary glacial till, outwash, lake sediments, and loess compose the surficial deposits of McHenry County (Figure 2) [2]. During the Quaternary period (2.6 million to 10,000 years before present), McHenry County experienced multiple glacial events during the Pre-Illinois, Illinois, and Wisconsin Episodes. Much of the landscape of McHenry County were formed by at least three separate advances of the Harvard Sublobe of the Wisconsin Episode Lake Michigan Lobe, which was part of the Laurentide Ice Sheet [2].

The youngest bedrock unit in McHenry County is the deposits is Silurian dolomite, which underlies the region's glacial deposits [2]. The fractured and creviced openings in the dolomite connect the groundwater of this Upper Bedrock Aquifer to the overlying sand and gravel aquifers of the Quaternary deposits [3].

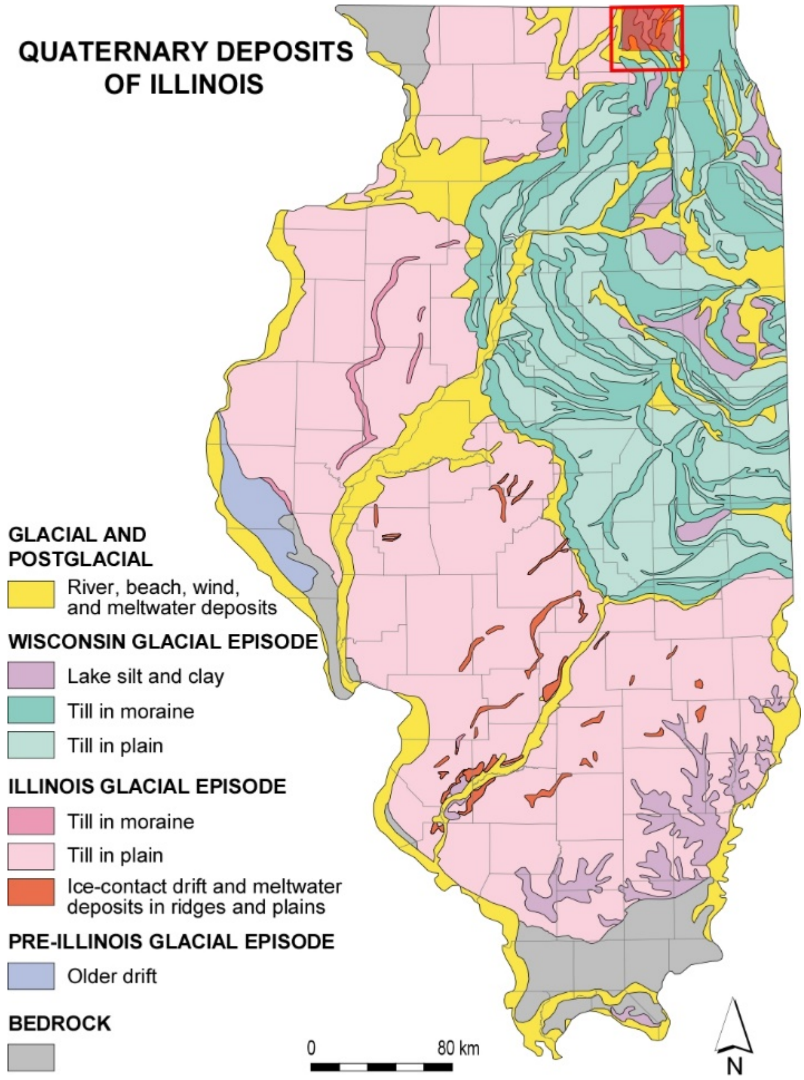

Figure 1. Surficial geologic map of Illinois showing the distribution of Quaternary glacial deposits. McHenry County is outlines in red. The pale red shading within is the study area. Map is modified ISGS Staff, 2005, Quaternary deposits: Illinois State Geological Survey, ISGS 8.5 × 11 map series

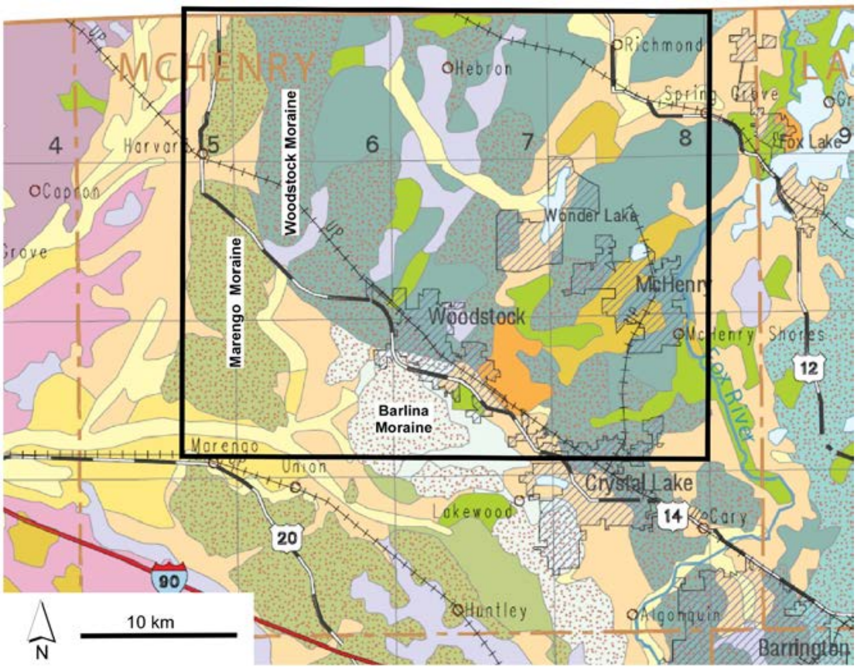

Figure 2. Surficial geologic map of Mclean County and surrounding areas (Modified from Stiff et al., [28]). Study area is outlined in black. Positions of the major moraines are indicated. Pink = Illinoisan units; Oranges = various outwash facies of the Henry Formation; Pale purple = Equality Formation, Dull green and teal = Wedron Formation, Bright green = Grayslake Peat; Yellow = Cahokia Alluvium

2. Previous Work

The Quaternary deposits in the northern United States and Canada have been increasingly utilized for human activities such as aggregate mining, waste disposal, and water supply [4]. Managing these demands, especially water supply, requires the best possible geologic mapping and modeling techniques to produce the optimal geologic models [5].

3-D geologic models provide the most accurate and detailed geologic information by showing the thickness and distribution of Quaternary units mapped from land surface to a determined depth which can then be used by other scientists and local governments to begin the process of modeling the more specific application of their choosing [6].

3-D modeling within Quaternary sediments has been ongoing in glaciated regions around the world. Multiple studies have been completed across southern Ontario and Quebec, Canada [e.g. [7,4,8,9,10]]. There have also been numerous studies in Europe [e.g. [6,11,12]]. Stumpf and Lumen [13] prepared an interactive 3-D geologic model of adjacent Lake County, Illinois. Willems et al. [14] prepared 3-D geologic model of the Ticona channel in north-central Illinois and interpreted it to have formed as a subglacial tunnel valley. Stumpf and Ismail [15] and Ismail et al. [16] developed 3-D geologic models of glacial sediments in the Teas-Mahomet buried bedrock valley in central Illinois.

Several recent studies used Petrel to model the geometry and stratigraphy of Quaternary glacial units. Hartz et al. [17] used seismic refraction data to develop a 3D model of Henry Formation valley train outwash in southern McLean County. Lau et al. [18] used Petrel to develop a geologic model of glacial deposits in adjacent Walworth County, WI. Carlock et al. [19] developed a 3-D model of glacial deposits overlying a CO_2 injection site near Decatur, Illinois.

The Quaternary glacial deposits in McHenry County have been a focus of scientific investigation for decades. Most of these studies were completed by scientists at the Illinois State Geological Survey. Willman and Frye [20] were the first to perform a comprehensive evaluation of the Pleistocene stratigraphy of Illinois, with several more studies to follow that focused more specifically on McHenry County deposits [3,21,22]. These publications focused on the stratigraphy, hydrology, and glacial geology of McHenry County. Recent work has focused on the sustainable use of Quaternary sediments for water resources [23].

Hansel and Johnson [24] revaluated the classification of the Wisconsin Episode deposits in the Lake Michigan Lobe area, to provide the current lithostratigraphic classification system for the units used within this study (Figure 3).

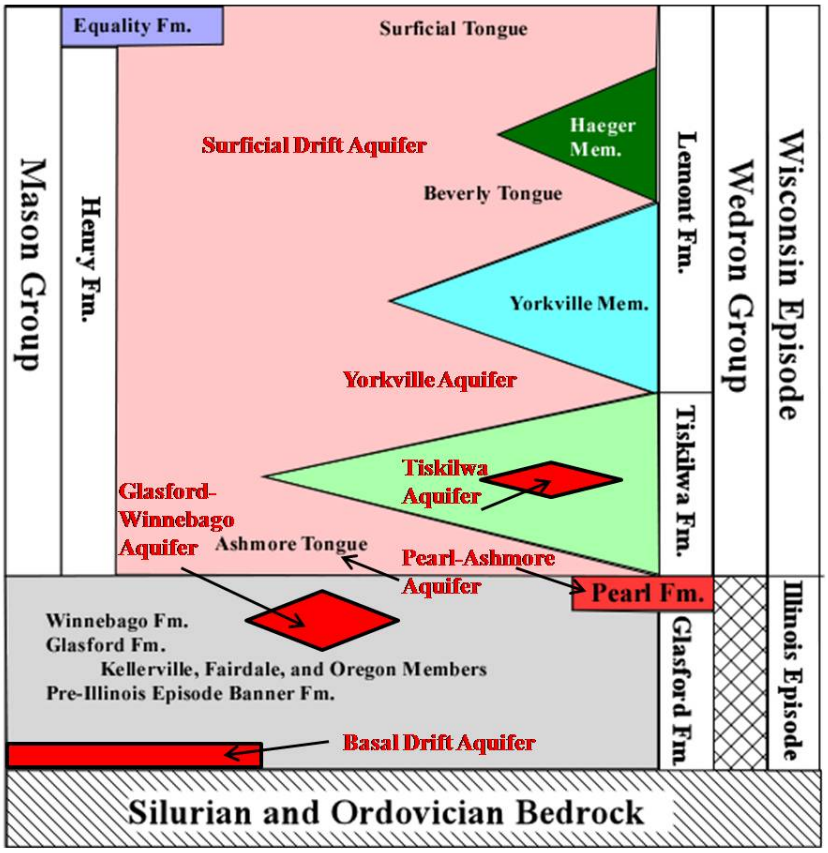

Figure 3. Stratigraphy of the study area including both lithostratigraphic an hydrostratigraphic units (red). Modified from [2]

3. Methodology

This 3-D geologic model was generated from a number of different subsurface geologic data sets. Among these are cross sections from Curry et al. *[2]*, McHenry County (MC) ISGS geologic borings, Northern Illinois Planning Commission (NIPC) ISGS geologic borings, and municipal and private water well records.

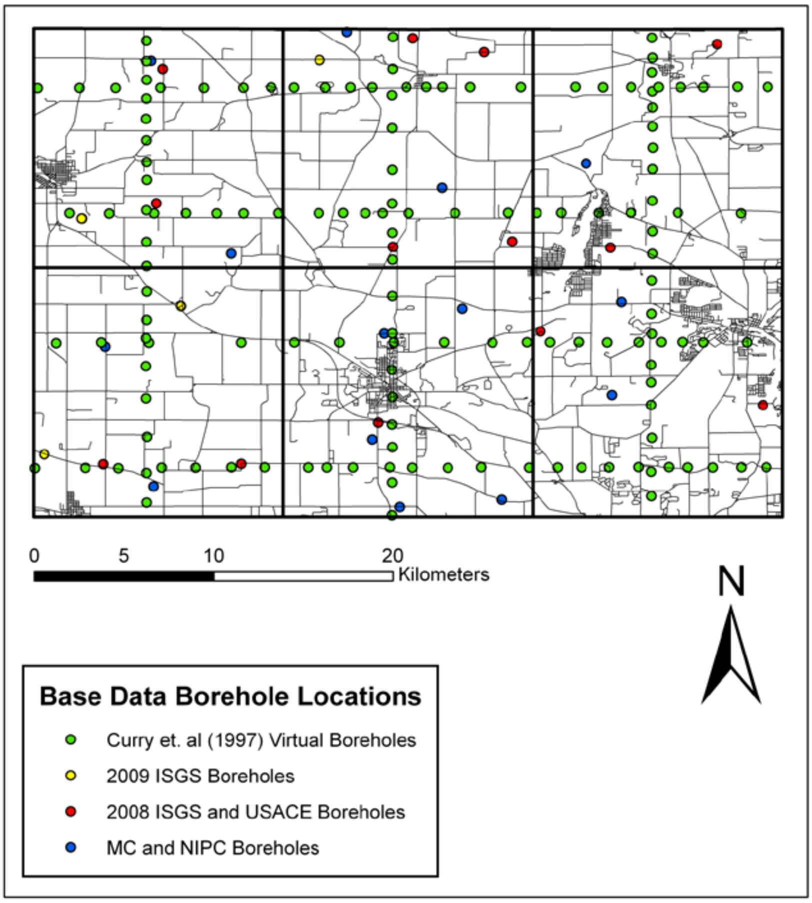

Figure 4. Study area map containing all boreholes used as geologic control data

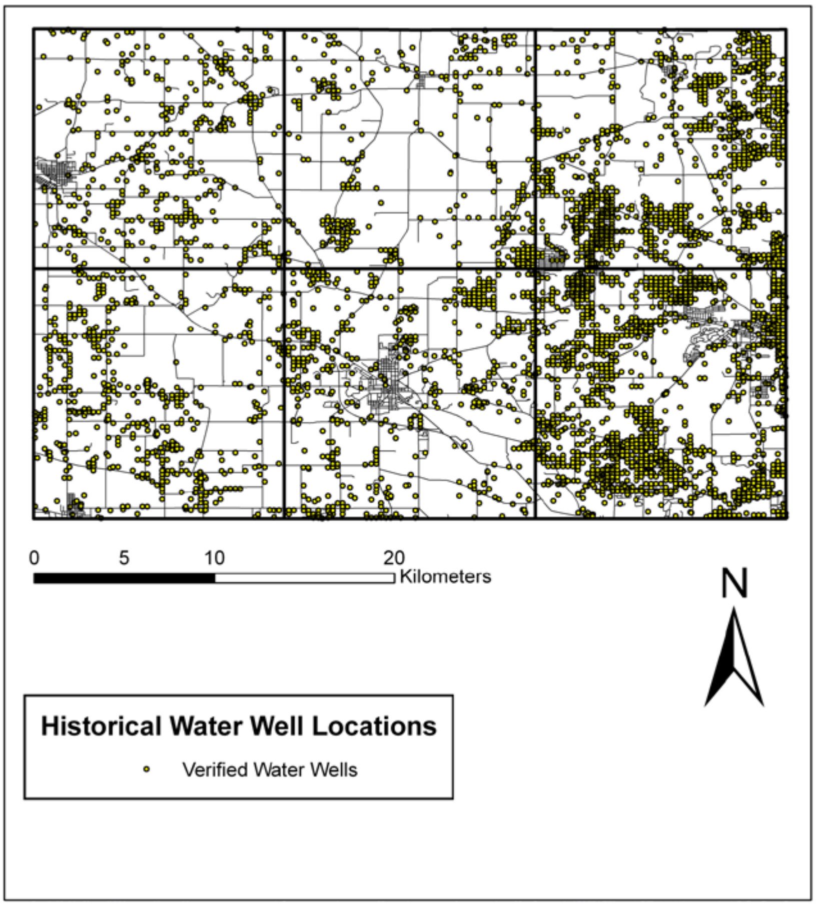

Figure 5. All historical water well records used to construct the 3-D geologic model

The Curry et al. [2] cross sections provided the bulk of the control data. The authors constructed a grid of cross sections that covered the entire county. Because the 3-D modeling software relies heavily on borehole data, virtual boreholes, which reflect the geology of the interpreted cross sections, were created along each profile transect. Synthetic borehole locations along these cross sections were chosen at intervals ranging from 1000 to 2500 m. Stratigraphic picks were then made by identifying the top elevations of each unit present at that location, thus creating virtual boreholes. Once all base data was collected, municipal and private water well records were obtained from the ISGS ILWATER database, which provided the bulk of the data. Figure 4 - Figure 5 show the locations of the data points used in the model. More than 700 wells were used to construct the model.

This water well data along with the base data borehole information were initially visualized and interpreted in the 3-D environment using *ESRI's ArcScene* and associated *ArcScene* tools developed by the Illinois State Geological Survey, which allowed for the manipulation of borehole data in the 3-D visual environment. Within the program, the boreholes are displayed in three dimensions allowing for the manipulation of each borehole's individual parameters. The control geologic data were used to help interpret lithologic descriptions found in the historical water well records.

Once the stratigraphic picks were made, they were imported into *Petrel* as well tops for the highest elevation of each individual unit (Figure 6). Top elevation surfaces were then created from these well tops within the program. Finally, horizons were created from the surface data to complete the 3-D geologic model. The horizon creation allows for the surfaces to be interpolated with respect to one another thus providing top and bottom elevations for each surface, or thickness.

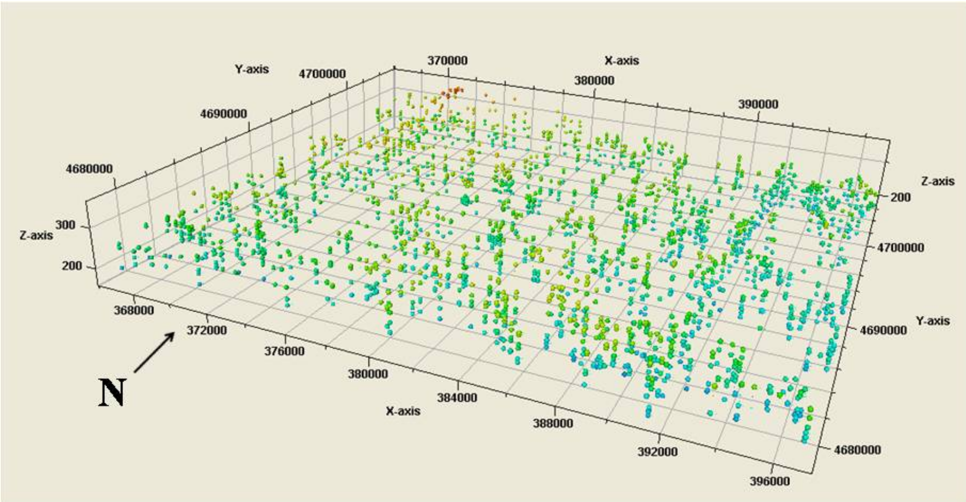

Figure 6. Screenshot of Petrel subsurface input data

4. Results and Discussion

The resulting 3-D geologic model contains the horizons created for ten Quaternary stratigraphic units (Figure 7 – Figure 8). The model measures approximately 34,000 m east to west by 30,000 m north to south and is up to 130 m thick in the buried bedrock valleys in the southeast portion of the model. These units modeled are, from youngest to oldest: Glasford Formation, Pearl-Ashmore aquifer, Tiskilwa Formation, Henry Formation, Yorkville Member of the Lemont Formation, Haeger Member of the Lemont Formation, and Equality Formation.

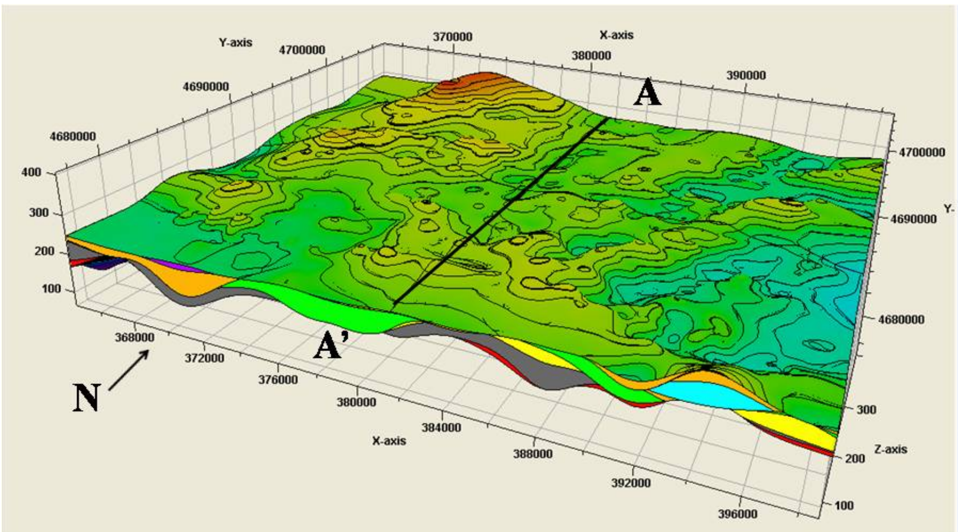

Figure 7. Completed 3-D geologic model. Red = basal drift aquifer; gray = Glasford Formation; Yellow = Pearl-Ashmore aquifer, Light green = Tiskilwa Formation, Orange = Henry Formation, Blue = Yorkville Member of the Lemont Formation; Dark green = Haeger Member of the Lemont Formation; Purple = Equality Formation

The Equality Formation is a thin, discontinuous surficial lacustrine layer associated with the termination of the most recent glacial advance. Isopach maps and the surficial geologic maps [25,26,27] indicate that the Equality Formation is most extensive in the north-central portion of the mapping in the Hebron Lowlands and reaches thicknesses of up to 10 m with an average thickness between 2.5 m and 5 m (Figure 9). This occurrence is nearly 12 m thick and is likely associated with the alluvial fans present off the leading edge of the Marengo Moraine.

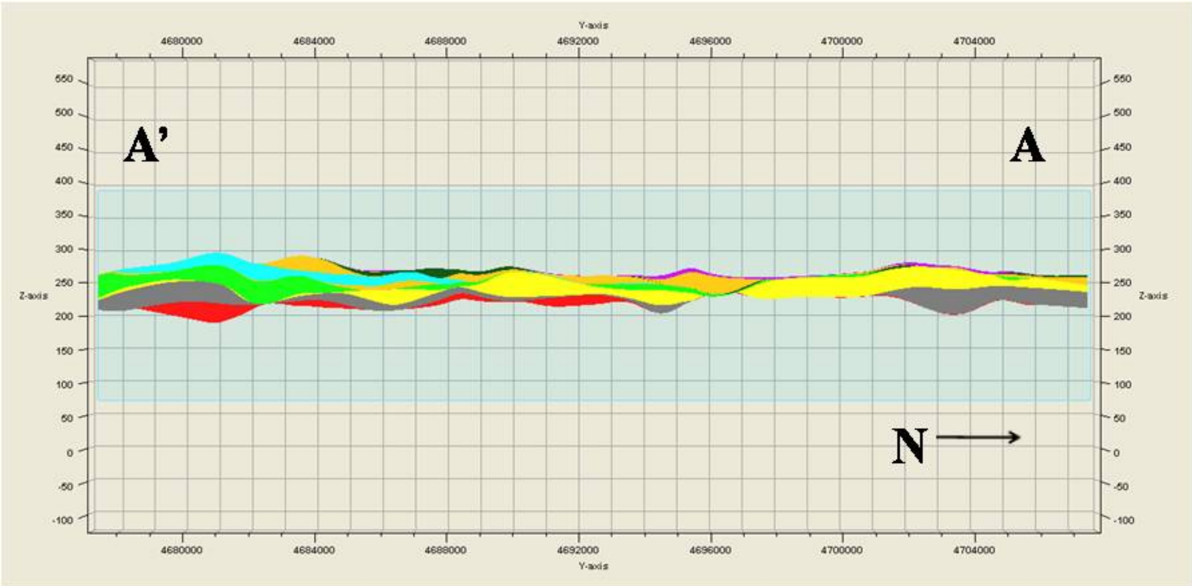

Figure 8. Cross Section A-A'. Colors are the same as in Figure 7. Z grid square = 1 km, X grid square = 50 m

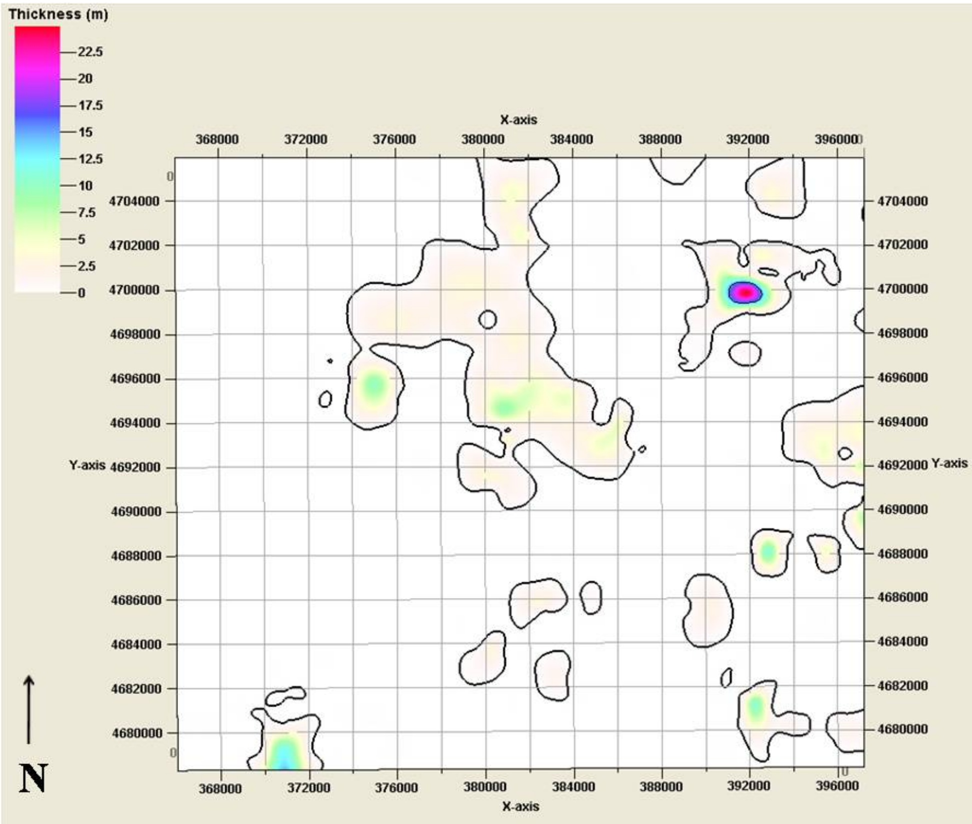

Figure 9. Isopach map of the Equality formation. Grid square = 4 km^2

The Henry Formation, Surficial Tongue, is an extensive surficial proglacial outwash sand and gravel deposit associated with the most recent glacial retreat. It is present throughout the modeling area and is associated with the Wonder Lake Valley system to the east and the alluvial fans and channel deposits of the Marengo and Woodstock Moraines in the central and western portions of the study area (Figure 10). It reaches thicknesses of as much as 40 m in the outwash systems located in the southwest portion of the study area, but is thickest within the Wonder Lake System where small pockets of sand and gravel can reach up to 80 m in thickness.

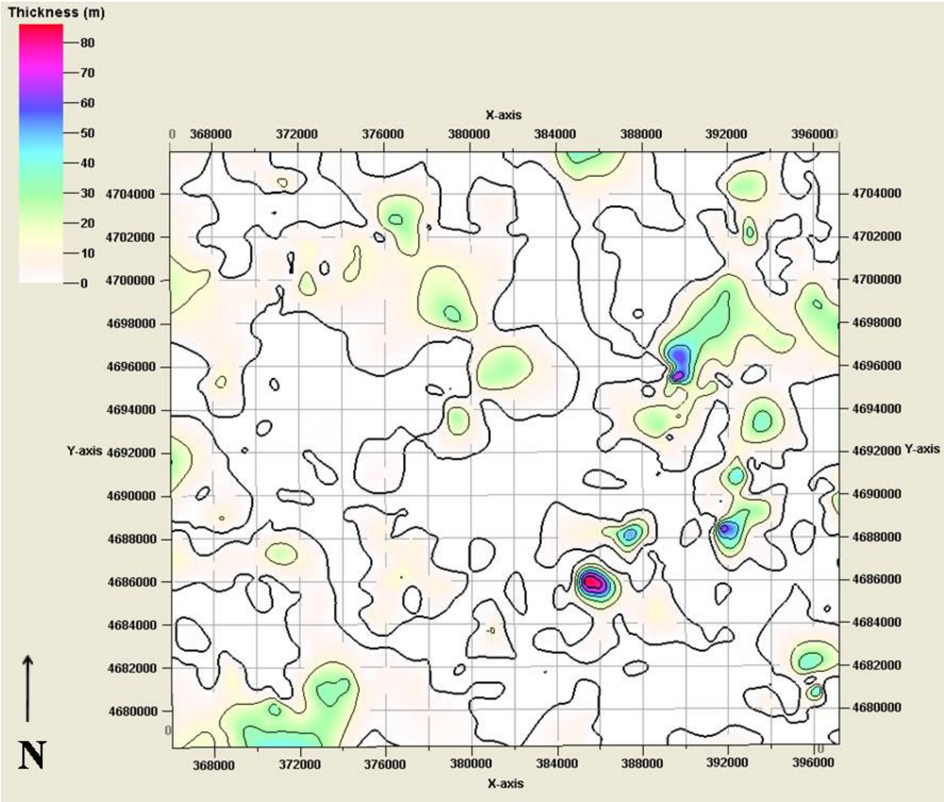

Figure 10. Isopach map of the Henry Formation, Surficial Tongue. Grid square = 4 km^2

The Lemont Formation, Haeger Member is a surficial subglacial deposit associated with the most recent glacial advance into the study area. Isopach maps indicate that it is continuous throughout the study area but commonly occurs in thicknesses of less than 5 m (Figure 11). The thickest occurrences of the Haeger Member are found in the Ringwood uplands near Hebron where it can be almost 20 m thick and also in deposits to the West which are up to 30 m thick and are associated with the Marengo-Woodstock Moraine.

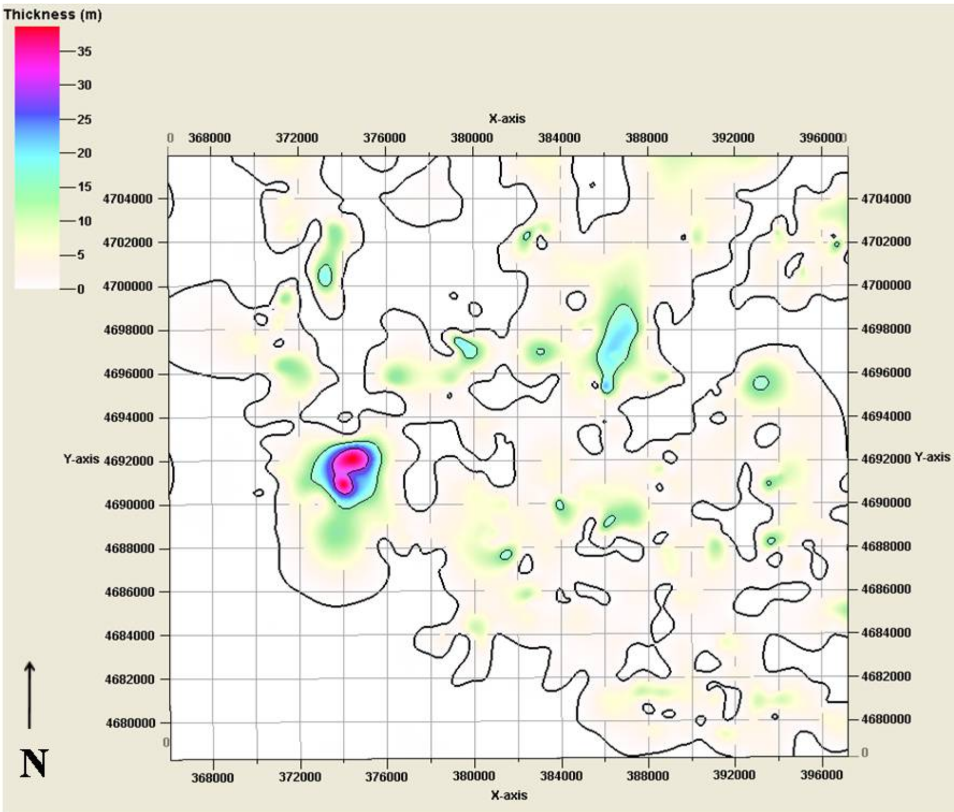

Figure 11. Isopach map of Lemont Formation, Haeger Member. Grid square = 4 km^2

Underlying the Haeger Member is the Beverly tongue of the Henry Formation, which is the proglacial outwash associated with the Haeger glacial advance. Curry et al. [2] indicated that the Henry Formation, Beverly Tongue was very closely related to the extent of the Haeger Member. Comparison of Figures 11 and 12 shows this relationship between the extents of the Haeger and Beverly deposits. The Beverly reaches its greatest thicknesses just behind the leading edge of the Marengo-Woodstock Moraine, which is the furthest advance of the Haeger Member. In these locations the Beverly can be as much as 45 m thick (Figure 12). Though the lumping of lithostratigraphic units within this model may not be entirely consistent with Hansel and Johnson [24], the lithologic character and thicknesses are still valid and certainly applicable to hydrogeologic concepts and water resource management.

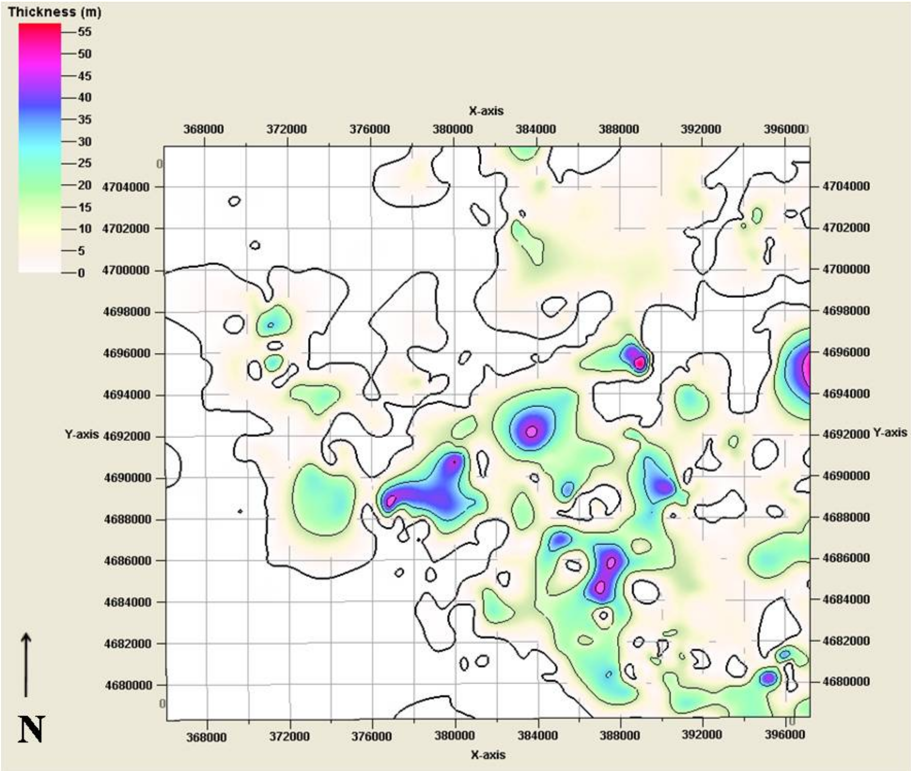

Figure 12. Isopach map of Henry Formation, Beverly Tongue. Grid square = 4 km^2

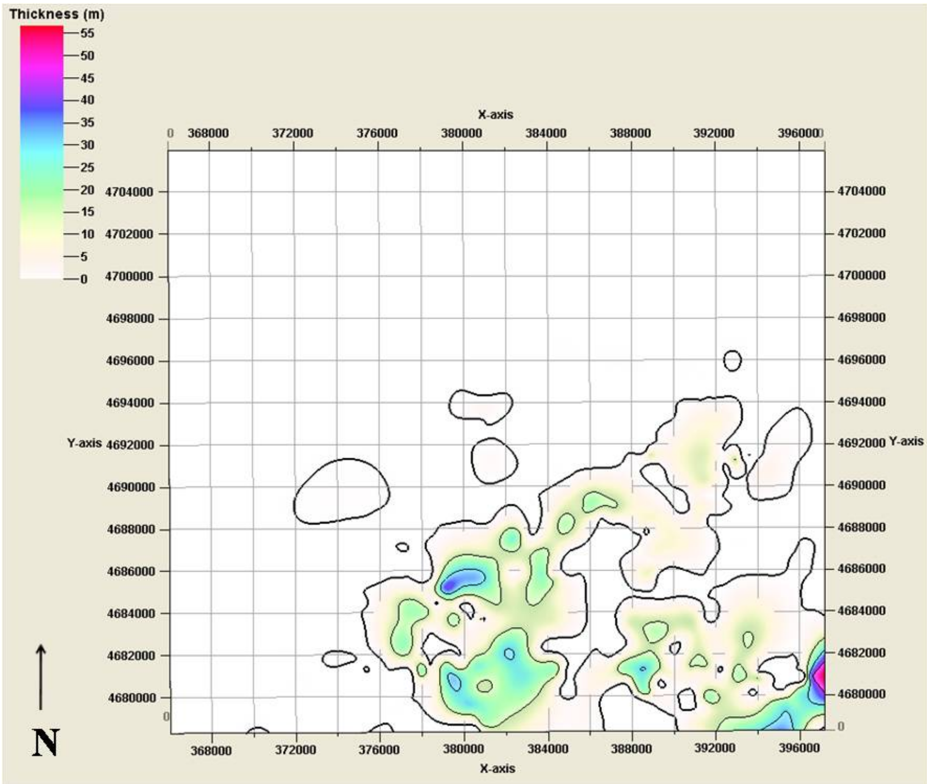

Figure 13. Isopach map of Lemont Formation, Yorkville Member. Grid square = 4 km^2

The Lemont Formation, Yorkville Member is absent in the northern portion of the study area, but where present it is associated with the Barlina Moraines in the southern portion of this mapping area. Curry et al. [2] suggested that the Yorkville Member was likely modified by erosion to the north or that thin discontinuous layers of the unit were deposited proglacially as opposed to under the ice and was therefore eroded as debris in front of the ice. Along the Barlina Moraine, modeled thicknesses of the Yorkville Member are up to 35 m (Figure 13).

The local sand and gravel outwash unit mapped below the Yorkville Member is modeled as the Yorkville Aquifer. This unit is, as expected, closely related to the extent of the overlying Lemont Formation, Yorkville Member. It is very discontinuous and generally has thicknesses of less than 5 m, although locally near the town of Woodstock it has been modeled to reach up to 35 m thick (Figure 14).

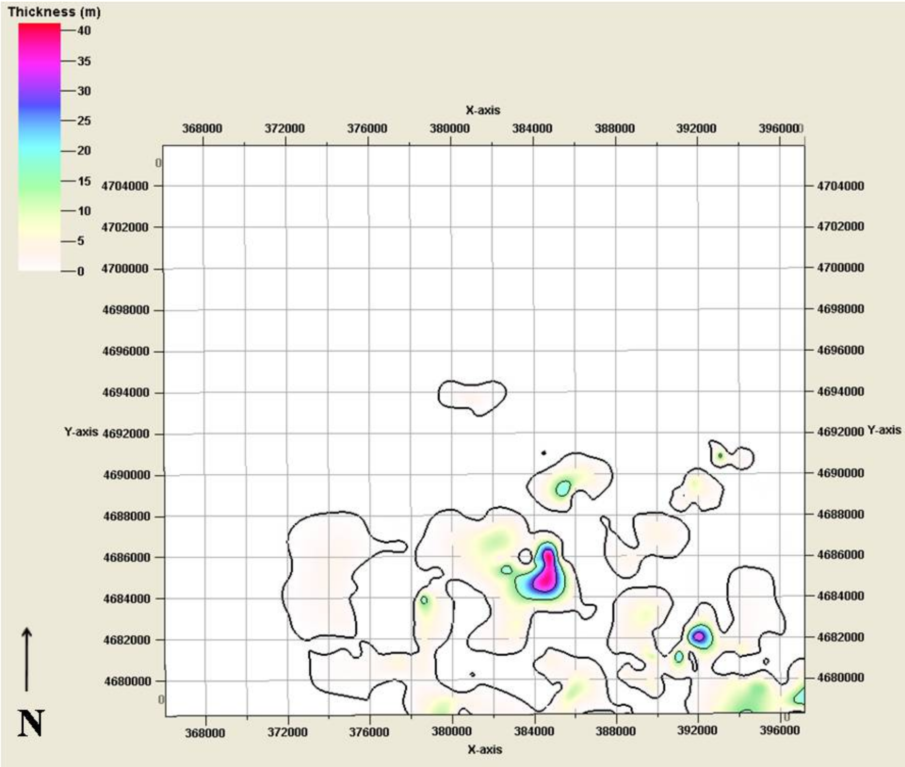

Figure 14. Isopach map of Yorkville Aquifer. Grid square = 4 km^2

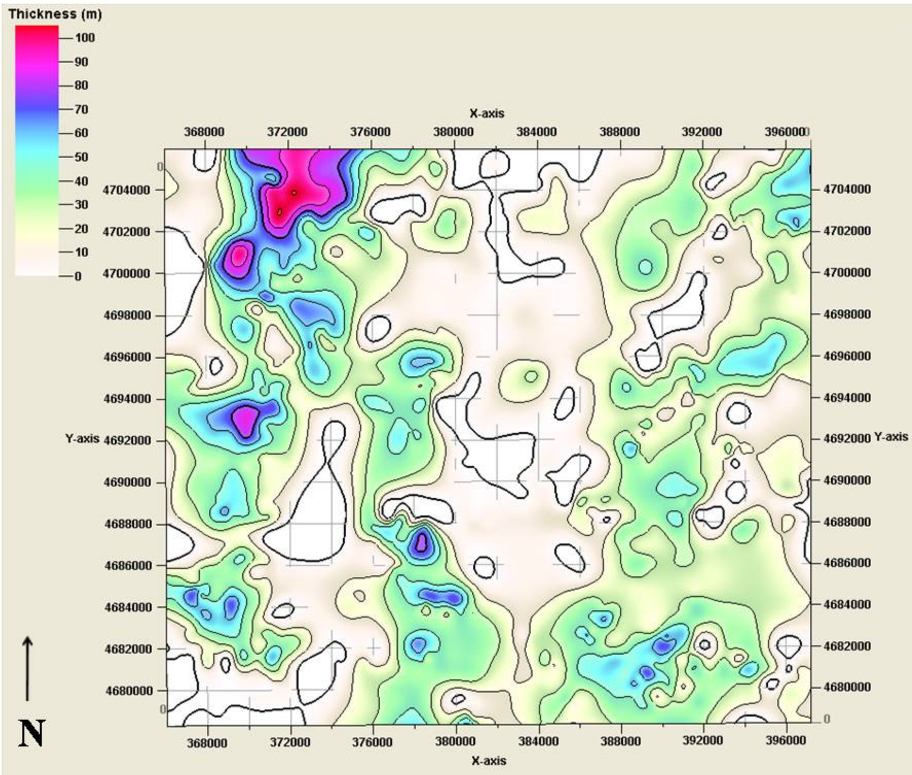

Figure 15. Isopach map of Tiskilwa Formation. Grid square = 4 km^2

The Tiskilwa Formation was deposited during the earliest and most extensive Wisconsin Episode glacial advance. It is found throughout the study area with thicknesses ranging from 20-50 m, but may reach thicknesses of up to 100 m in the northwest corner of the mapping area where deposits make up the Marengo Moraine, the Wisconsin Episode's furthest advance in McHenry County (Figure 15). Interestingly it is absent in the Wonder Lake System where the unit has been eroded and replaced by the younger sand and gravel deposits of mostly the Beverly Tongue. The Tiskilwa Formation is also notably absent from the central portion of the mapping area within the Hebron Lowlands and extending south throughout the town of Woodstock.

The Pearl-Ashmore Aquifer, which is the focus of this study, is the combination of the proglacial outwash of the Wisconsin Episode Ashmore Tongue of the Henry Formation and the youngest outwash associated with the Illinois Episode, which is the Pearl Formation. This combination of two lithostratigraphic units leads to a thicker and more complex succession of sand and gravel deposits. Isopach maps from Curry et al. [2] indicate that the Pearl-Ashmore Aquifer extends throughout the study area at thicknesses of between 5 and 10 m (Figure 16).

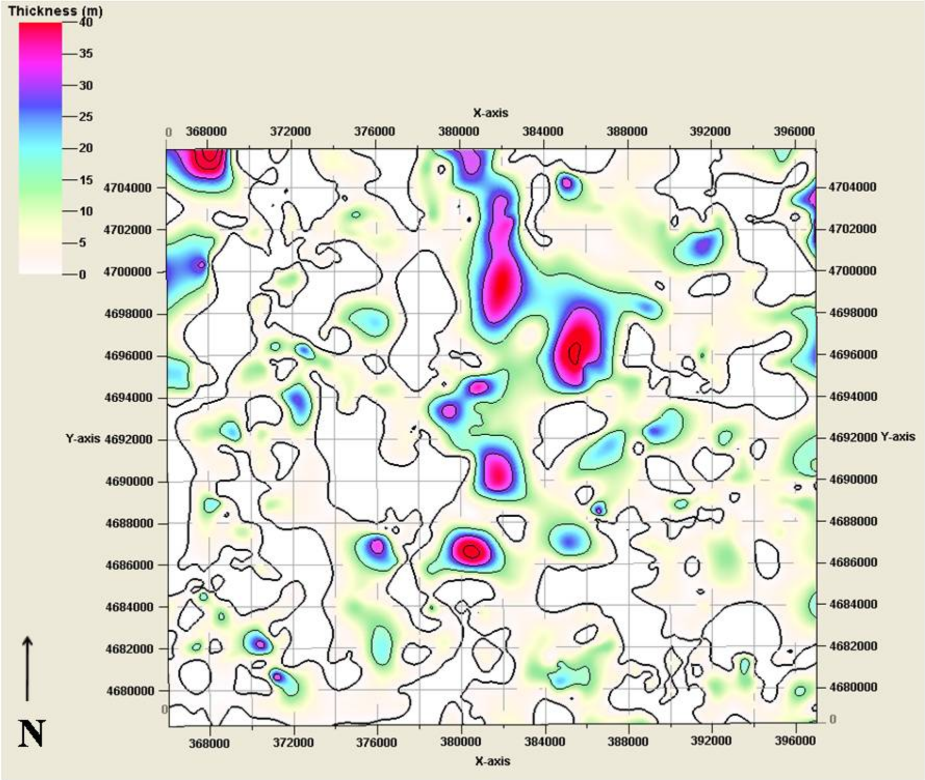

Figure 16. Isopach map of Pearl-Ashmore Aquifer. Grid square = 4 km^2

Curry et al. [2] indicated that the Pearl-Ashmore Aquifer was a thick (25-30 m) channel-like deposit extending nearly 20 km through the Hebron Lowlands. The larger data set modeled here have added detail to the original interpretation. This model indicates that, rather than a linear channel geometry, the Pearl Ashmore trends north-northeast before abruptly changing direction to northwest-southeast. The unit reaches thicknesses of up to 40 m. The unit is geometrically related to the Wonder Lake Valley to the east and thus is likely genetically related to that system as well. The origin of the Wonder Lake Valley is interpreted as a series of connected valleys which were modified during the Woodstock Phase as meltwater from the retreating glacier eroded the valleys and filled them with sand and gravel [2]. The sand and gravel deposits found in the Hebron Lowlands resemble this geometry may be an earlier deposit of this type.

The Glasford Formation is the Illinois-age proglacial outwash unit, which, for this study was grouped with other Illinois age outwash units as the Glasford Formation, undivided. The Oregon, Fairdale, and Kellerville Members of the Glasford Formation are included in this formation, but very little sand and gravel is mappable as a marker bed for lithostratigraphic-unit separation. Thus, for simplicity of the model, any subglacial deposits older than the Wisconsin Episode were grouped together. The Glasford extends through the majority of the mapping area, occurring at thicknesses varying from 10 to 50 m (Figure 17). The Glasford Formation thickens to the west, because these deposits were not likely subjected to the glacial erosion of the younger Wisconsin Episode glaciations.

The Basal Drift Aquifer was modeled as any sand and gravel deposit that underlies the Glasford Formation and unconformably overlies the bedrock surface. This unit was distinguishable unit in most well records. It serves as an important water resource to local communities (especially domestic wells). This unit is sporadic in the study area and reaches thicknesses of 10 to 20 m (Figure 18). There are a few anomalies where thicknesses reach up to 60 m or more. Curry et al. [2] indicated that the Basal Drift Aquifer could be as much as 100 m thick beneath the Marengo Moraine. No thicknesses of this magnitude were evident in this model.

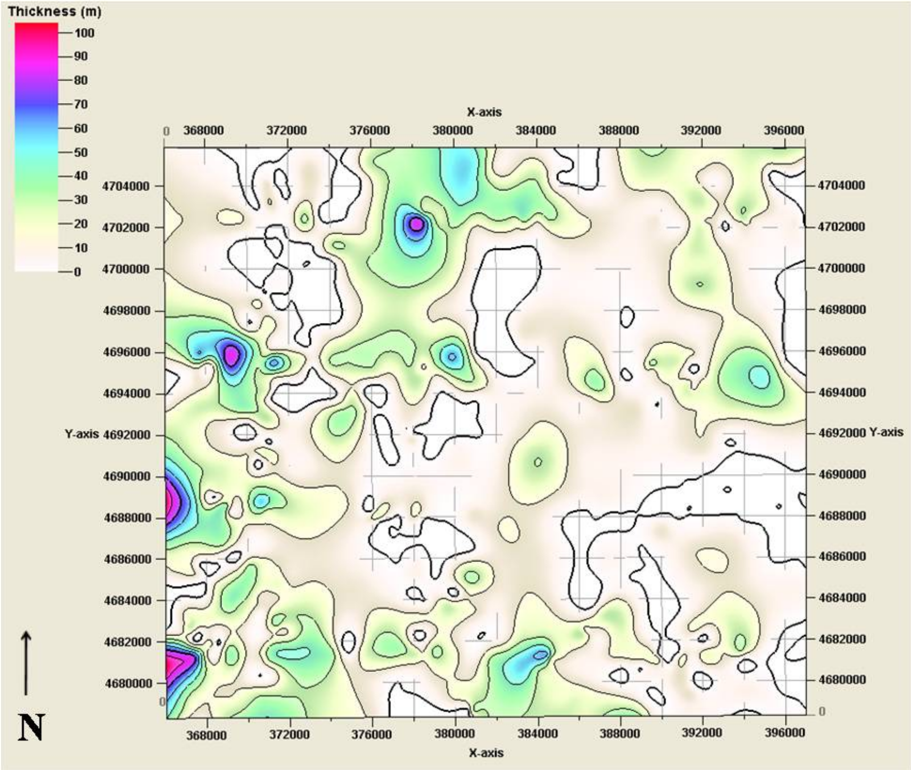

Figure 17. Isopach map of Glasford Formation. Grid square = 4 km^2

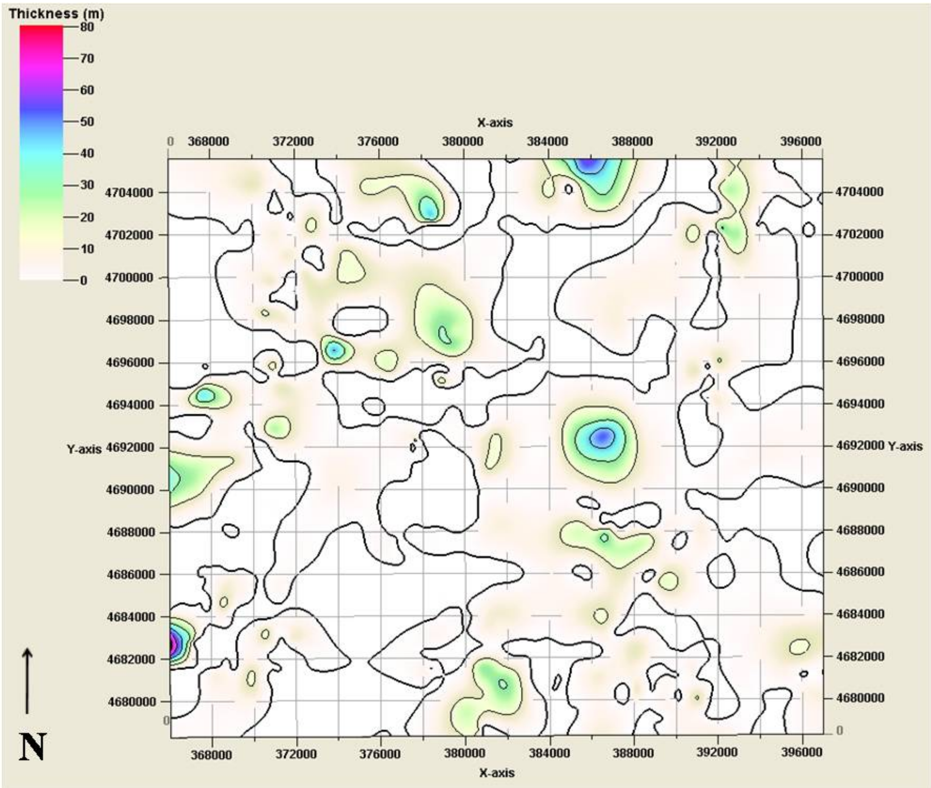

Figure 18. Isopach map of Basal Drift Aquifer. Grid square = 4 km^2

The elevation of the bedrock surface was the base of the model. Because this study focused on the Quaternary glacial sediments, these units were again lumped as a single layer to simplify the model. The bedrock surface shows has a relief of 125 m. The bedrock elevation slopes to the east from paleoelevations of about 250 m in the northwest portion of the mapping area to 210 m in the east. Several bedrock valleys appear throughout the study area, most notably in the Wonder Lake region where relief changed by 50 m and in the western portion of the mapping area two distinct bedrock valleys are present which have nearly 100 m of relief. These are most likely associated with the Troy Bedrock Valley which intersects the northwest portion of McHenry County, just west of the study area.

5. Conclusions

The Pearl-Ashmore Aquifer is an important groundwater resource for the communities in north-central McHenry County. It provides all the fresh water to the town of Woodstock and the smaller communities that surround it. A detailed investigation of the extent, thickness, and variability of the sand and gravel aquifer was needed in order to better understand the complex geometry and architecture of this unit, which will aid in studies of local and regional aquifer systems.

The Pearl-Ashmore Aquifer extends through the eastern two-thirds of McHenry County. The 3-D geologic model predicts that the aquifer has an average thickness ranging from 5 to 15 m and is thickest in the north-central portion of McHenry County where it can reach thicknesses of up to 40 m. Added borehole data has increased the resolution of the geometry of the Pearl-Ashmore Aquifer with respect to previous mapping efforts of the unit. Curry et al. [2] mapped these thickest deposits of the aquifer as a linear channel, however the larger data set in this study have indicated that the aquifer more represents the meandering type deposit similar to that of the Wonder Lake System to the east. Based on age of the units and position with respect to the ice margins in the county, the Pearl-Ashmore Aquifer at this location represents an earlier deposit of this type that was either short lived or incised to a lesser degree by meltwater. The Pearl-Ashmore Aquifer is also notably missing throughout the modeling area to the west where the Tiskilwa Formation (the age equivalent sub-glacial till of the Ashmore Tongue of the Henry Formation) is thickest and forms the end moraines of the oldest Wisconsin age glacial advance. The Pearl-Ashmore Aquifer is also missing to the east where it has been presumably eroded by the younger incision of the Wonder Lake Valley System. In addition to the architecture of this unit, hydrologic assumptions can be inferred from the 3-D geologic model.

Implications for the movement of groundwater within this entire system can be derived from the contact relationships of the Pearl-Ashmore Aquifer and the other Quaternary units. Of particular importance is the communication of the Pearl-Ashmore Aquifer with the other sand and gravel aquifers mapped. The Pearl-Ashmore Aquifer is recharged where it is in contact with the Surficial Aquifer, which may also create conduits for contamination to reach the unit.

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