UNIVERSITY OF MINNESOTA
MINNESOTA GEOLOGICAL SURVEY
Harvey Thorleifson, Director

Prepared and Published with the Support of
THE KANABEC COUNTY BOARD OF COMMISSIONERS,
THE MINNESOTA DEPARTMENT OF NATURAL RESOURCES, DIVISION OF ECOLOGICAL AND WATER RESOURCES,
AND THE MINNESOTA ENVIRONMENT AND NATURAL RESOURCES TRUST FUND
AS RECOMMENDED BY THE LEGISLATIVE-CITIZEN COMMISSION ON MINNESOTA RESOURCES

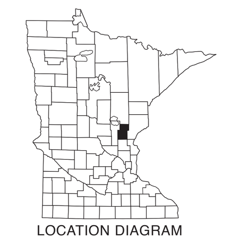
COUNTY ATLAS SERIES
ATLAS C-38, PART A
Kanabec County
Plate 5—Bedrock Topography, Depth to Bedrock, *and* Sand-Distribution Model

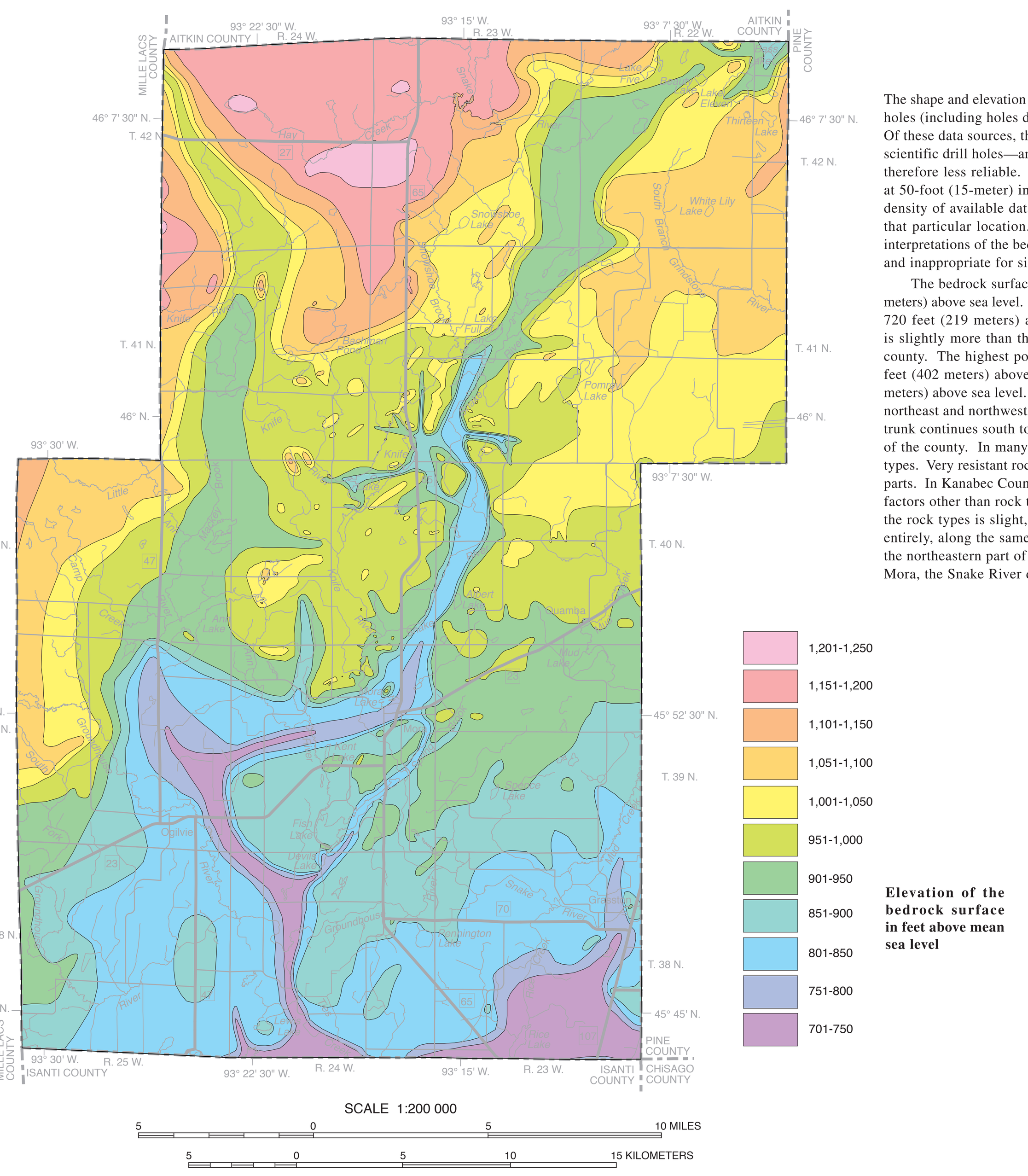
BEDROCK TOPOGRAPHY

By

Dale R. Setterholm

2016





Digital base modified from the Minnesota Department of Transportation BaseMap data; digital base annotation by the Minnesota Geological Survey.

Universal Transverse Mercator Projection, grid zone 15; 1983 North American Datum

GIS compilation by R.S. Lively
Edited by Lori Robinson

EXPLANATION

The shape and elevation of the bedrock surface was determined from records of water wells and scientific drill holes (including holes drilled for this project), from passive seismic soundings, and from mapped outcrops. Of these data sources, the outcrops are regarded as the most reliable, water wells and drill holes—especially scientific drill holes—are quite reliable, and passive seismic soundings are helpful, but more interpretive and therefore less reliable. The topography data were interpreted by a geologist and the contours were drawn at 50-foot (15-meter) intervals. At a given location, the user should always take into account the type and density of available data, as illustrated on Plate 1, *Data-Base Map*, to assess the reliability of the map for that particular location. Areas with a high density of bedrock control points are likely to have accurate interpretations of the bedrock elevation, whereas areas with widely spaced control points may be less reliable and inappropriate for site-specific needs.

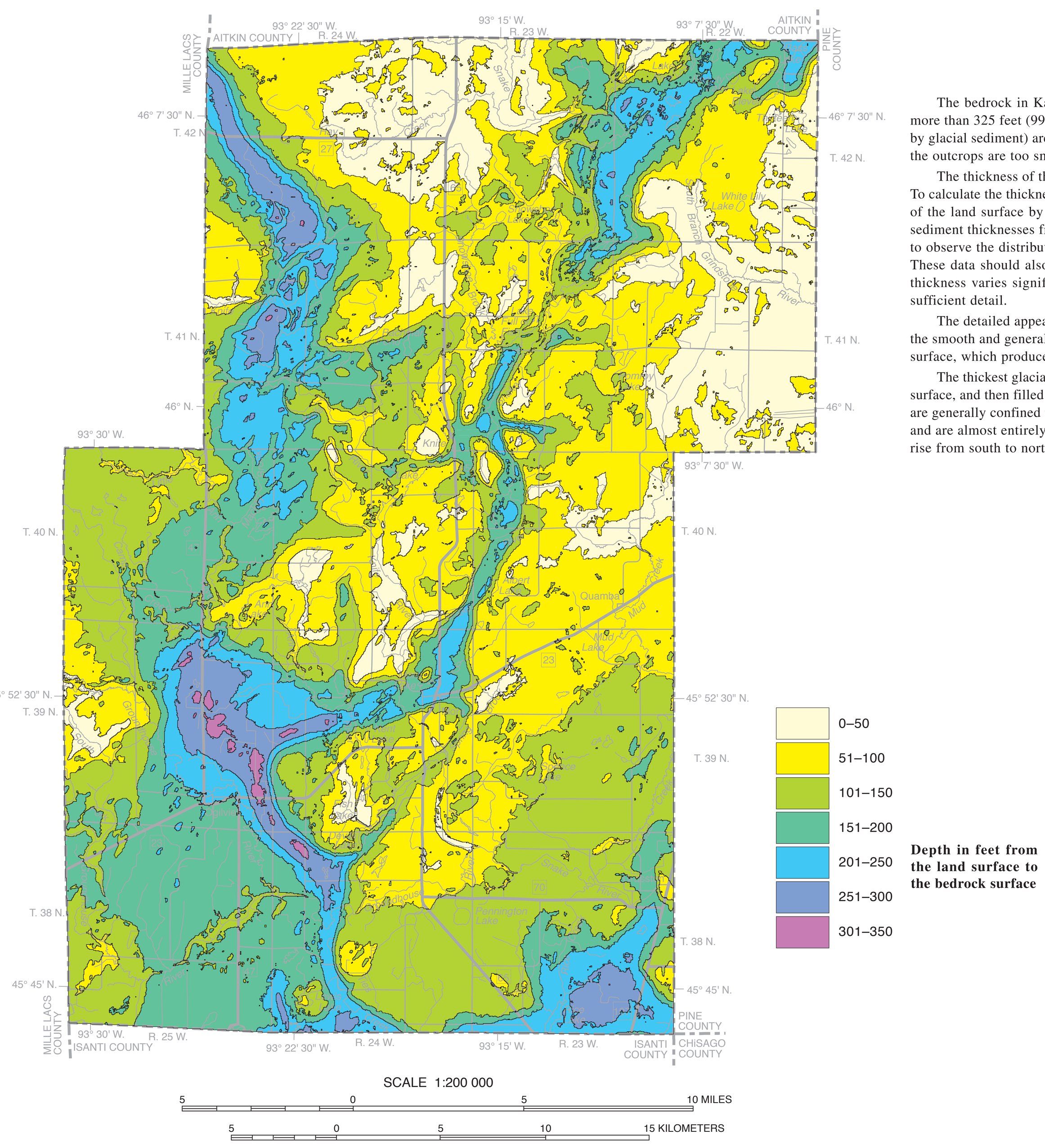
The bedrock surface is highest in the north-central part of the county, where it exceeds 1,200 feet (366 meters) above sea level. It is lowest where a valley exits the southeastern corner of the county at approximately 720 feet (219 meters) above sea level. The 500 feet (152 meters) of total relief on the bedrock surface is slightly more than the approximately 390 feet (119 meters) of relief on the present land surface of the county. The highest point of the land surface is in the northwestern part of the county that exceeds 1,320 feet (402 meters) above sea level. The lowest point of the land surface is slightly less than 940 feet (287 meters) above sea level. The largest feature of the bedrock surface is a Y-shaped low with limbs reaching the northeast and northwest corners of the county. The limbs join in the south-central part of the county and the trunk continues south to the county border, where it abruptly turns east and exits at the southeastern corner of the county. In many parts of Minnesota the shape of the bedrock surface correlates with different rock types. Very resistant rock types generally underlie the high areas, and less resistant rock types underlie lower parts. In Kanabec County this correlation is not apparent. Erosion of the bedrock surface was controlled by factors other than rock type, such as ice dynamics, or the relative difference in resistance to erosion among the rock types is slight, and less of a factor. The present course of the Snake River occurs mostly, but not entirely, along the same path as the northeast-trending bedrock valley. This co-occurrence continues from the northeastern part of the county south to the vicinity of Mora. In some places, such as just northwest of Mora, the Snake River does not overlie the bedrock valley and it has exposed bedrock.

DEPTH TO BEDROCK

By

Dale R. Setterholm

2016



Digital base modified from the Minnesota Department of Transportation BaseMap data; digital base annotation by the Minnesota Geological Survey.

Universal Transverse Mercator Projection, grid zone 15; 1983 North American Datum

GIS compilation by R.S. Lively
Edited by Lori Robinson

EXPLANATION

The bedrock in Kanabec County is mostly covered by glacial sediment that varies from a few feet to more than 325 feet (99 meters) thick. Those areas where the bedrock is exposed at the surface (not covered by glacial sediment) are called outcrops, and their distribution is shown on Plate 1, *Data-Base Map*. Some of the outcrops are too small to be included on the printed map, but they are included in the digital version.

The thickness of the glacial sediment is equal to the depth from the land surface to the bedrock surface. To calculate the thickness at any place, the elevation of the bedrock surface was subtracted from the elevation of the land surface by digital methods. The resulting thicknesses were checked against measured glacial sediment thicknesses from drilling records, and adjusted where necessary. As with any map, it is important to observe the distribution of available data, seen on Plate 1, to evaluate the reliability of the derived map. These data should also be considered when working at site-specific scales. There are places where drift thickness varies significantly over short distances, and mapping at the 1:200,000 scale may not provide sufficient detail.

The detailed appearance of the Depth to Bedrock map is an artifact of the digital process of subtracting the smooth and generalized elevations of the bedrock surface from the highly detailed elevations of the land surface, which produces a map that retains more detail than is supported by the data.

The thickest glacial sediment in Kanabec County occurs where valleys have been eroded into the bedrock surface, and then filled with glacial sediment. Glacial sediment thicknesses greater than 175 feet (53 meters) are generally confined to these valleys. Bedrock outcrops occur between the two major bedrock valley limbs and are almost entirely at elevations of 950 feet (290 meters) above sea level or higher. Outcrop elevations rise from south to north across the landscape.

SAND-DISTRIBUTION MODEL

By

Elizabeth L. Dengler and Jacqueline D. Hamilton

2016

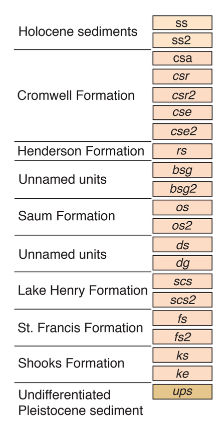


Figure 1. Stratigraphic column of sand and gravel units, and associated formations, identified in Kanabec County. This includes the sand and gravel units that appear on this plate and those that are exclusively in the digital files. The full stratigraphic column with associated till and lake sediments appears on Plate 4, *Quaternary Stratigraphy* (Fig. 10).

INTRODUCTION

The sand and gravel deposits of Minnesota are the products of a long glacial history that complicates the mapping of potential water-bearing units in the subsurface. Establishing the location and characteristics of these sand and gravel units is an essential step toward identifying aquifers, and ensuring their appropriate use and protection. In an effort to delineate the sand and gravel units in Kanabec County, a geologist familiar with the region and a Geographic Information Systems (GIS) specialist collaborated to create a sand-distribution model showing the location of these potential aquifers. Although the sand-distribution model and the resulting interpretations are based on the best available data, they are unavoidably incomplete due to an uneven distribution of data.

The surficial sand and gravel deposits were mapped using exposures, shallow drill holes, soil maps, water-well logs, and landforms. In contrast, interpreting sand-distribution in the subsurface primarily used water-well records as recorded by drillers, scientific drill core, and drill cuttings as described by geologists. Each well record or log is an interpretation of the stratigraphy at that precise location. The geologist assessed the accuracy of the varied interpretations and used this information to predict the extent and distribution of the sediments. These predictions are based on an analysis of the available data and an understanding of the glacial history and processes that deposited the sediment. The distribution of data greatly influences the resolution and accuracy of the sand-distribution model. Where data are lacking, both at the surface and at depth, limited interpretations can be made. The characterization, stratigraphic correlation, thickness, and extent of buried units are therefore not as well constrained as the surficial units.

The unconsolidated Quaternary sediments that occur between the land surface and the top of bedrock in Kanabec County vary in character and thickness, and were deposited by numerous glacial advances during the Pleistocene Epoch (Plate 4, *Quaternary Stratigraphy*). Multiple sequences of sand and gravel were deposited by meltwater that flowed from these ice lobes. Unsorted sediment deposited directly by the ice (till), and bedded sediments of clay, silt, and fine-grained sand deposited in ponded meltwater, both supraglacially and proximal to the ice, locally form confining layers that enclose the sand and gravel bodies. Because the till units were deposited directly by the ice that spread across the county, they tend to be more laterally continuous than the sand and gravel units that were deposited within meltwater channels. Additionally, sand and gravel deposits are more easily eroded than till units during subsequent glaciations; as a result, sand and gravel units tend to be laterally discontinuous. Even across short distances, the extent and thickness of any given sand and gravel body is difficult to predict.

In order to create valid a sand-distribution model of the subsurface of Kanabec County, 47 closely spaced (0.6 mile [1 kilometer]) east–west cross-section lines were generated (Plate 4, Fig. 1). Water-well and rotary-sonic core records (Plate 1, *Data-Base Map*) along these lines were used by a geologist to identify contacts between units in the subsurface. In well logs, till is commonly described as "clay" by well drillers. Although sand and gravel bodies can occur within a till unit, they more commonly occur at the contact between two till sheets. Where two clay (till) layers related to different depositional events are not separated by a sand and gravel layer, their contact can be recognized in some cases by a change in the driller's description of the clay's texture (for example, clay/sandy clay/clay and gravel), density, or color. Using the available data, contact lines were drawn along each cross section, with each line representing the base of a geologic unit. The final interpretations along six of these cross sections are shown on Plate 4, *Quaternary Stratigraphy*. GIS software was used to extract elevation values from vertices along each unit line on the cross sections. The elevation values were used to create a gridded elevation surface representing the extent of each geologic unit within the county. These surfaces were iteratively modified until the geologist was confident that they adequately represented the stratigraphic interpretation for each geologic unit. The finalized base grids were then used to create additional top and bottom grids as well as thickness grids for each geologic unit. The result is a three-dimensional geologic model of till and sand and gravel units for the county.

Sand and gravel units are listed in stratigraphic order from youngest to oldest (Fig. 1). The more extensive sand and gravel units portrayed by the sand-distribution model are shown in Figures 2 through 10, ranging from the youngest units at the land surface, to buried and progressively older sand and gravel units at depth.

The sand-distribution model outputs (Figs. 2 through 11) should be considered probability maps for the occurrence and approximate thickness of major sand and gravel units. The sand-distribution model does not guarantee sand and gravel bodies will be found at all places shown, nor does it preclude them from being found in areas where they are not shown. Thin sand and gravel bodies (less than 10 feet [3 meters]) commonly did not survive the processing that created the multiple surfaces. Wells typically do not penetrate the complete thickness of sand and gravel layers, resulting in drillers' logs commonly underreporting sand and gravel-body thickness. As a result, some of the sand and gravel bodies shown on the cross sections (Plate 4) may be thicker and more widespread than portrayed. At increasing depths in the stratigraphic section, data availability diminishes and delineated sand and gravel bodies may be more or less continuous than shown.

Not all of the water wells in Kanabec County extend through the full thickness of the Quaternary deposits and therefore deep Pleistocene deposits cannot be differentiated in all places (Fig. 10). However, thicker sand and gravel bodies are commonly present where deep drill holes occur. Additional sand and gravel units, or extensions of those mapped, are undoubtedly present in these undifferentiated parts of the Pleistocene section. Despite these limitations, the sand-distribution model provides a realistic depiction of the characteristics and distribution of geologic units in the subsurface of Kanabec County. However, given the limitations of the data, as noted above, the model should be used as a guide and should not preclude further site-specific investigations or inspection of individual well logs.

A number of factors determine whether or not the sand and gravel units depicted here are usable aquifers. To be an aquifer the units must be saturated and able to readily transmit water to a well. Their capacities for water storage and transmission depend on their extent and thickness, as well as factors such as sediment coarseness, degree of sorting, consolidation, and potential for recharge. Connectivity between the sand and gravel units is also important. In many places two or more sand and gravel units may connect to form a single aquifer if there is no intervening till layer. Water quality also determines whether an aquifer is suitable as a source of drinking water. The maps and reports produced by the Minnesota Department of Natural Resources, as Part B of the County Geologic Atlas mapping program, take these and other factors into consideration to characterize hydrogeologic conditions.

CONTOURS FOR FIGURES 2 THROUGH 9

Thickness of a sand and gravel unit contoured at 20 foot (6 meter) intervals.

- 20
- 40
- 60
- 80
- 100
- 120 and greater

Note: Contour lines may not close at the edges of mapped areas. This is an artifact of the digital processing.

DEPTH FOR FIGURES 3 THROUGH 10

- 0–50
- 51–100
- 101–150
- 151–200
- 201–250
- 251–300
- 301–350
- 351–400

Depth in feet from the land surface to the top of a sand and gravel unit (depth from the land surface to the top of undifferentiated sediment is shown on Figure 10).

SCALE 1:300 000

5 0 5 10 MILES

5 0 5 10 KILOMETERS

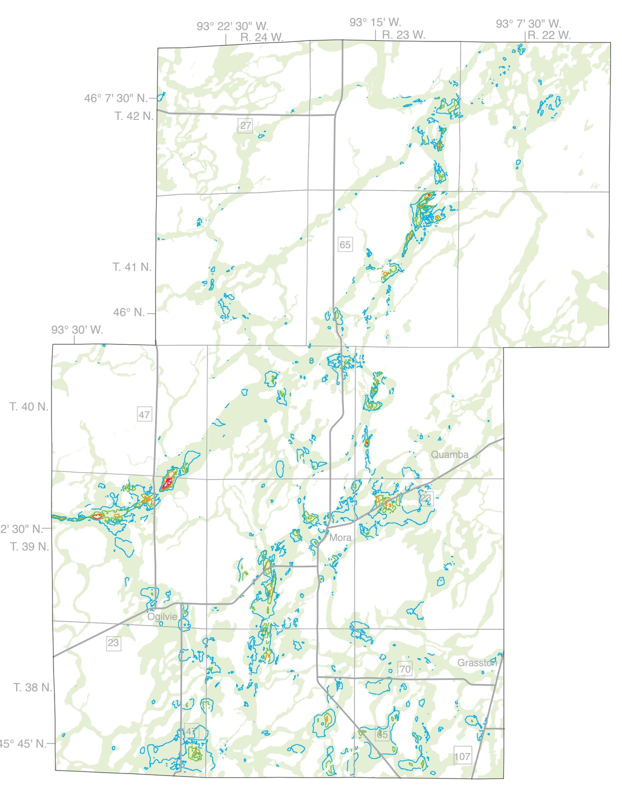


Figure 2. Surficial sand bodies—Model-generated map of the extent and thickness of sand and gravel bodies occurring at the land surface in Kanabec County. Includes units ss, ss2, and csa. The surficial sand is overlain in places by peat and other fine-grained sediment (units pe, cl, ncl, and cla from Plate 3, *Surficial Geology*), and locally by surficial till unit cta0 (Plate 4, *Quaternary Stratigraphy*).

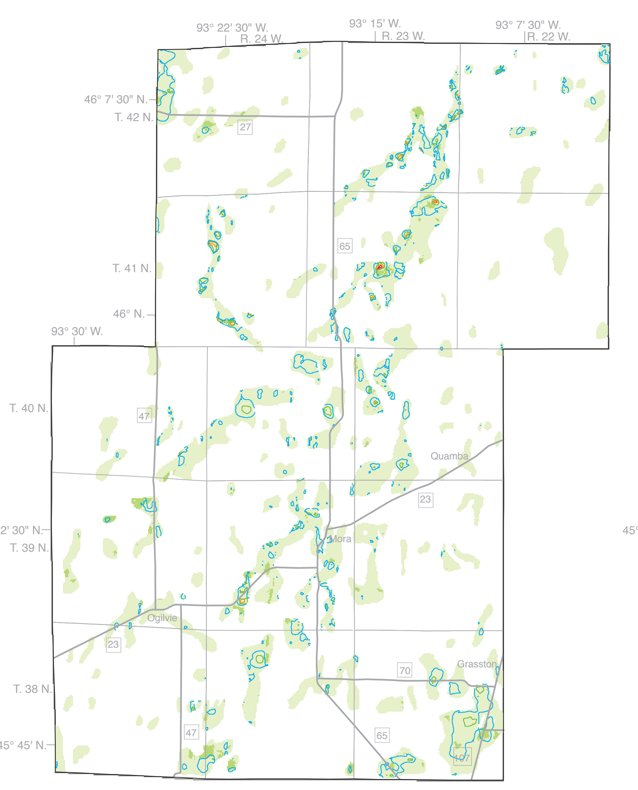


Figure 3. Sand and gravel units *csr* and *csr2*—Model-generated map of the extent, depth from the land surface, and thickness of sand bodies that commonly lie stratigraphically immediately above till unit *ctr*, but in places may overlie older units. Primarily deposited by meltwater from the receding Superior-provenance ice during the St. Croix phase.

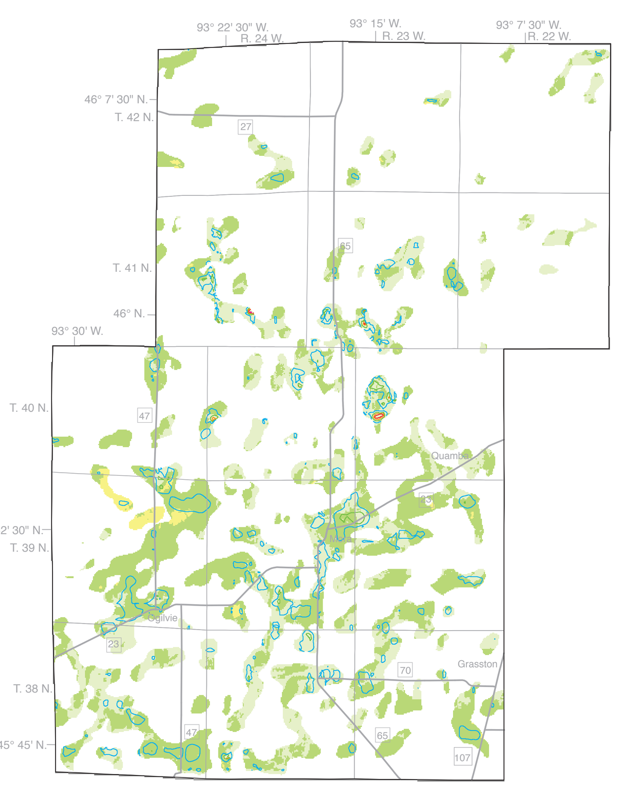


Figure 4. Sand and gravel units *cse* and *cse2*—Model-generated map of the extent, depth from the land surface, and thickness of sand bodies that commonly lie stratigraphically immediately above till unit *cte*, but in places may overlie older units. Primarily deposited by meltwater from the receding Superior-provenance ice during the Emerald phase.

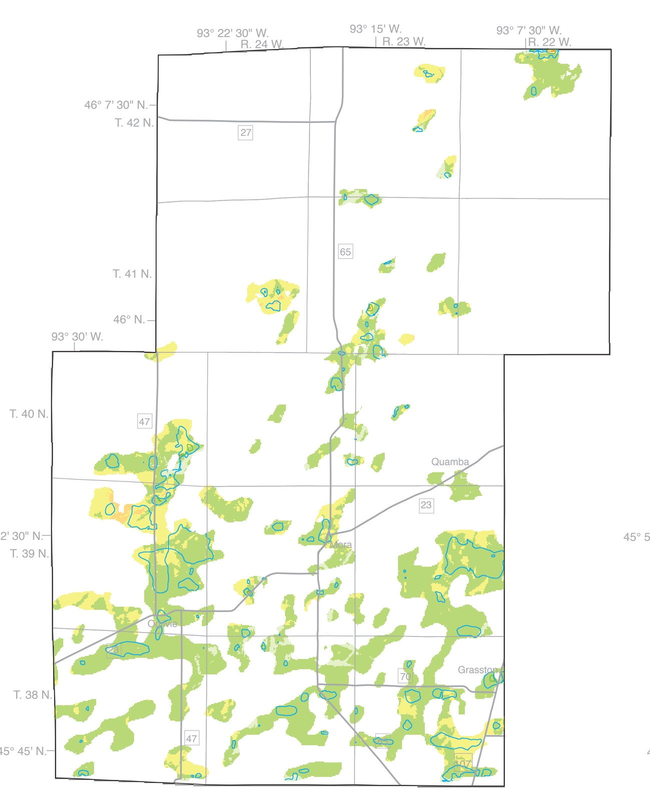


Figure 5. Sand and gravel units *bsg* and *bsg2*—Model-generated map of the extent, depth from the land surface, and thickness of sand bodies that commonly lie stratigraphically immediately above till unit *bt*, but in places may overlie older units. Primarily deposited by meltwater of the receding Superior-provenance ice.

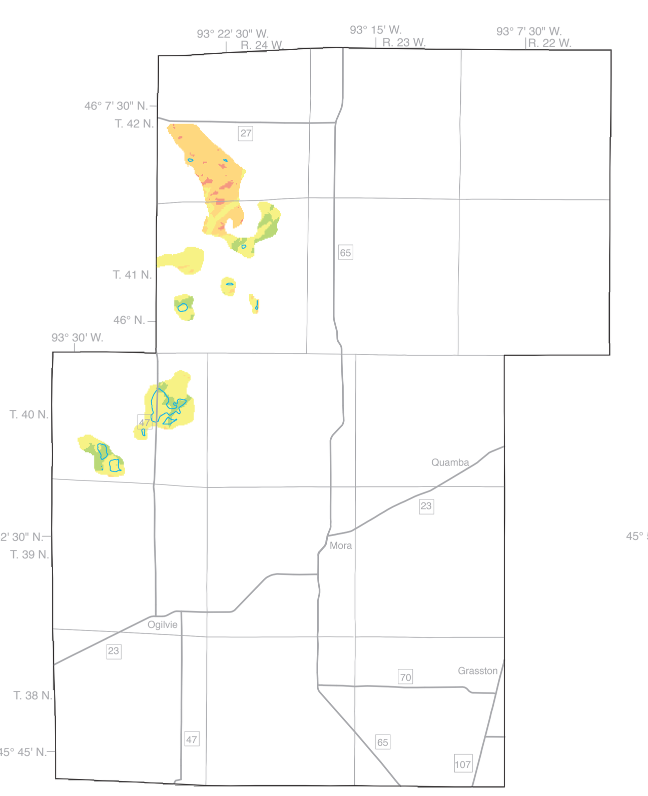


Figure 6. Sand and gravel units *os* and *os2*—Model-generated map of the extent, depth from the land surface, and thickness of sand bodies that commonly lie stratigraphically immediately above till unit *ot*, but in places may overlie older units. Primarily deposited by meltwater of the receding Rainy-provenance ice.

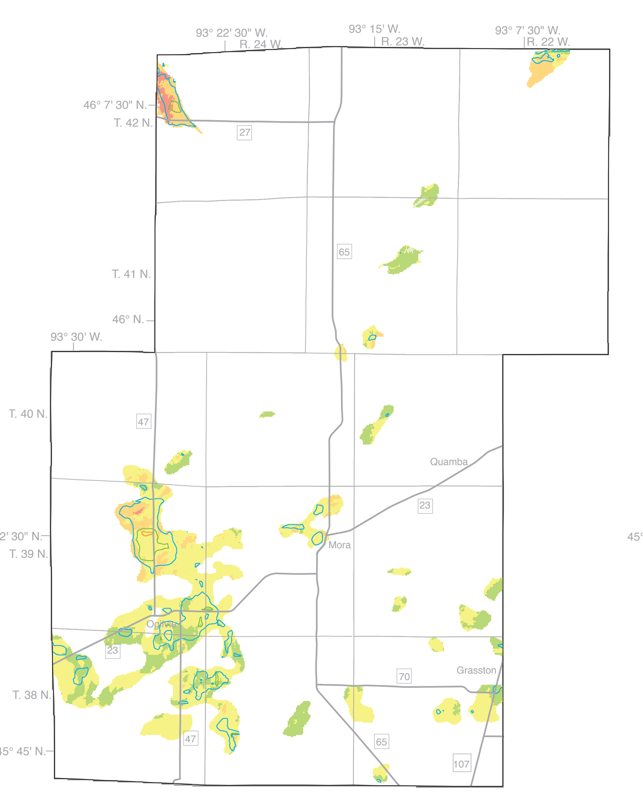


Figure 7. Sand and gravel unit *ds*—Model-generated map of the extent, depth from the land surface, and thickness of sand bodies that commonly lie stratigraphically immediately above till unit *dt*, but in places may overlie older units. Primarily deposited by meltwater of the receding Superior-provenance ice.

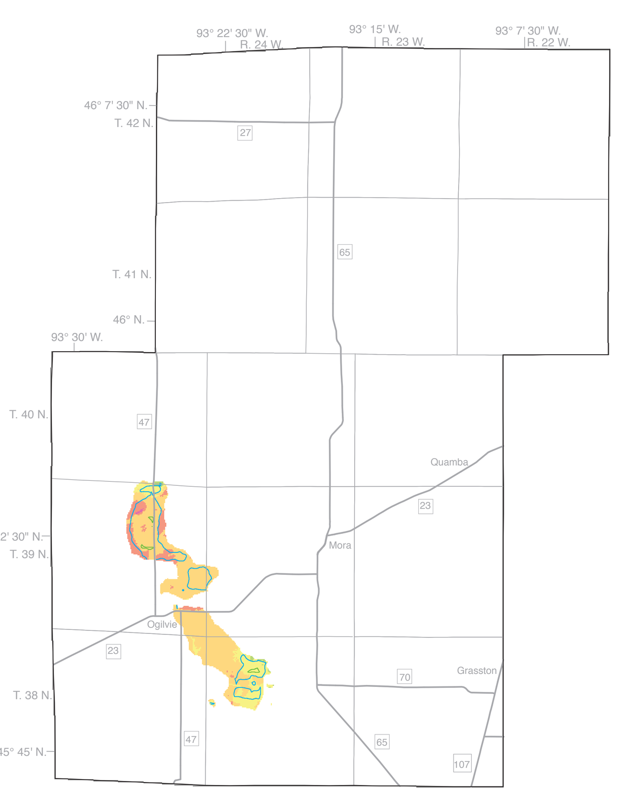


Figure 8. Sand and gravel units *fs* and *fs2*—Model-generated map of the extent, depth from the land surface, and thickness of sand bodies that commonly lie stratigraphically immediately above various older units. Primarily deposited by meltwater of the receding Superior-provenance ice.

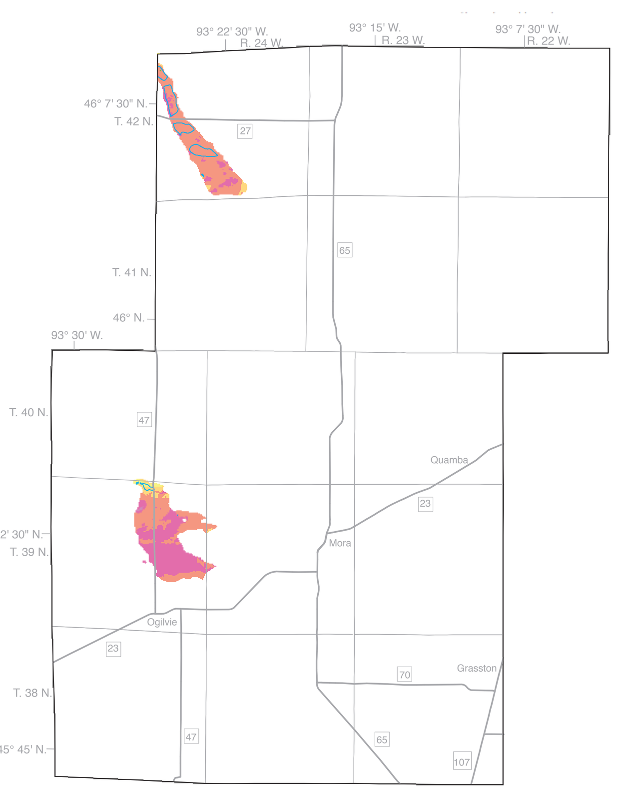


Figure 9. Sand and gravel unit *ks*—Model-generated map of the extent, depth from the land surface, and thickness of sand bodies that commonly lie stratigraphically immediately above various older units. Primarily deposited by meltwater of the receding Rainy-provenance ice.

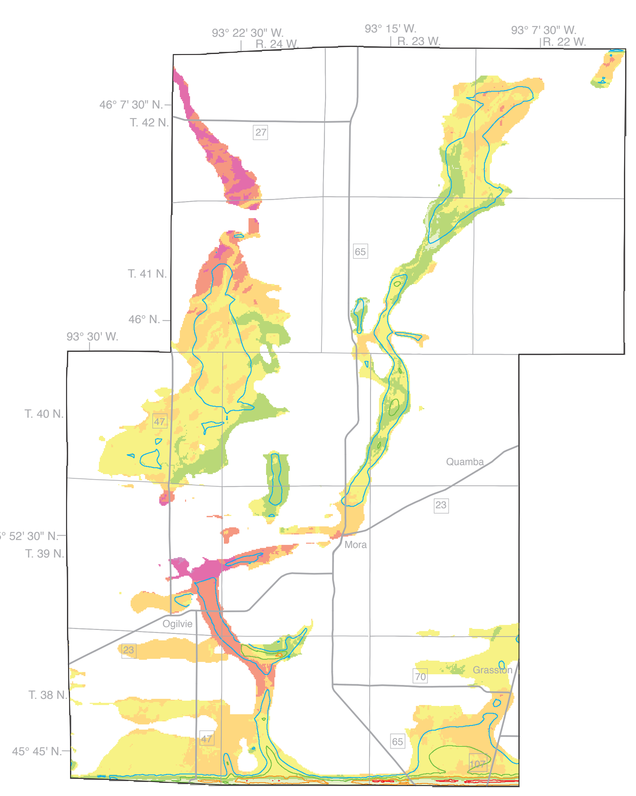


Figure 10. Undifferentiated Pleistocene sediment (unit *ups*)—Model-generated map of the extent, depth from the land surface, and thickness of Pleistocene sediment for which no descriptive data are available. This unit underlies all identifiable units in Kanabec County. The east to west linearity of this unit in the southern half of the county is an artifact of a lack of data at depth, rather than a deliberate decision by the Quaternary geologist.

CONTOURS FOR FIGURE 10: 50, 100, 150, 200 — **Thickness of undifferentiated sediment.**

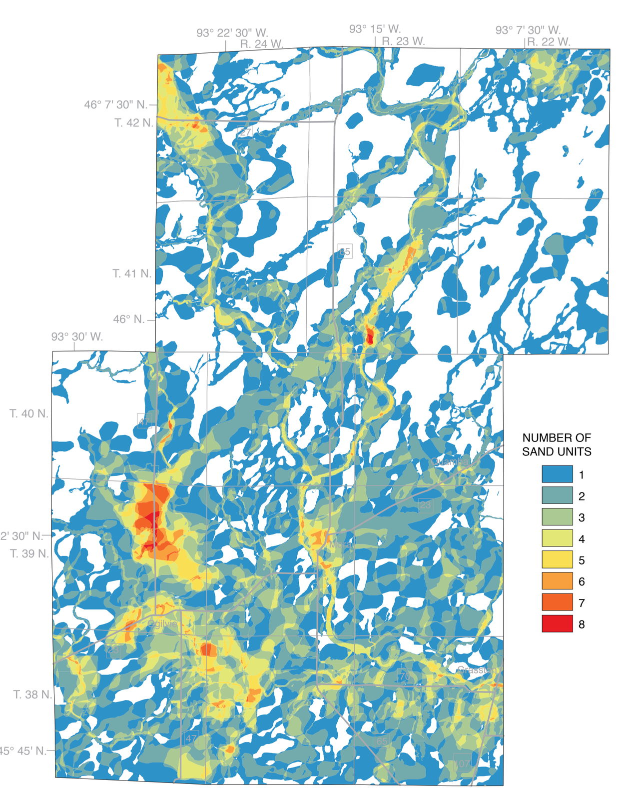


Figure 11. Sand units—Model-generated map of the extent and number of Quaternary sand units (as defined in the model) encountered between the land surface and bedrock. Note that overlying sand units are not necessarily interconnected. White areas have no mapped sand units.

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND