UNIVERSITY OF MINNESOTA
MINNESOTA GEOLOGICAL SURVEY
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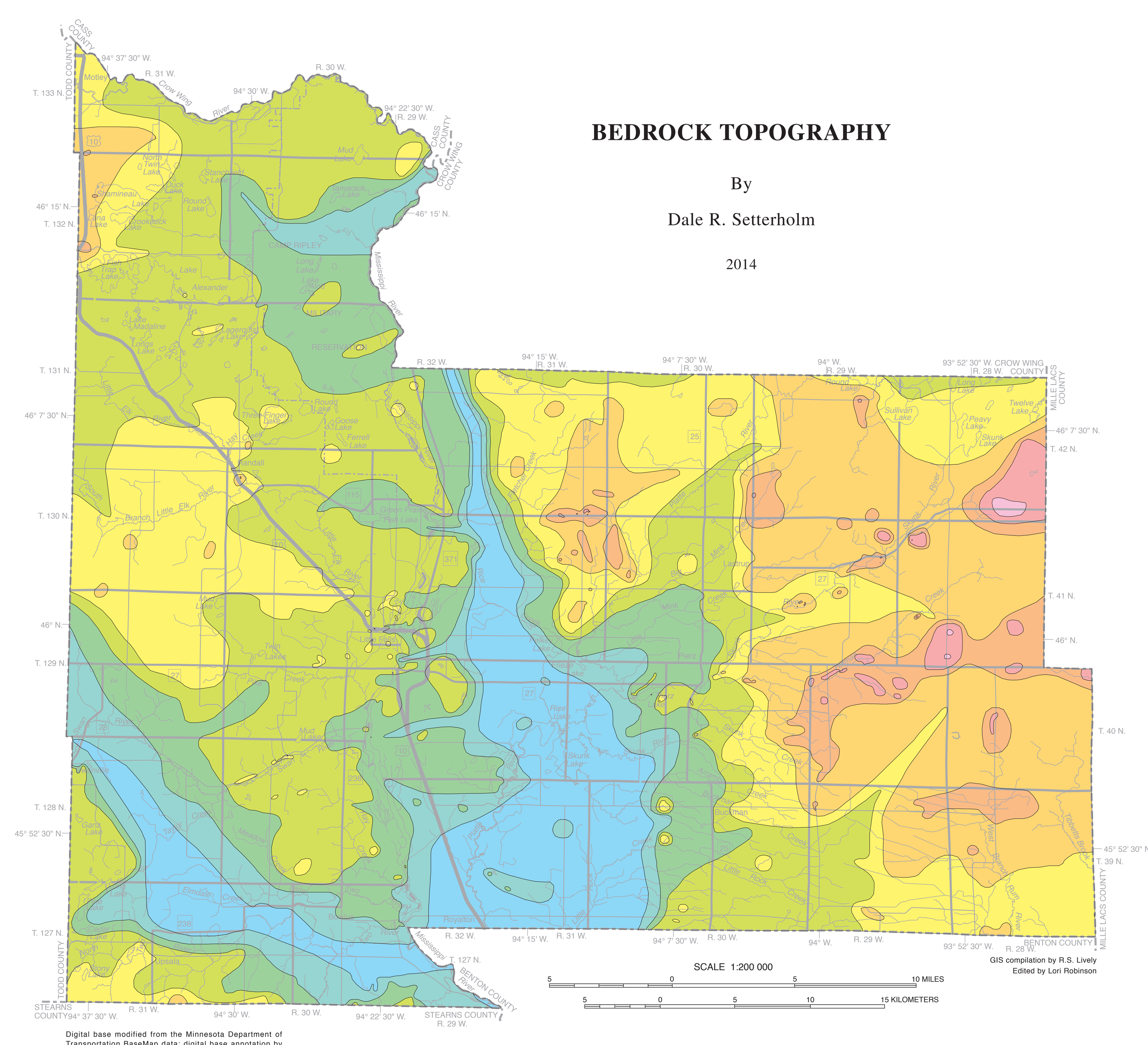
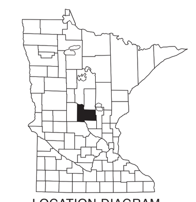


BEDROCK TOPOGRAPHY

By

Dale R. Setterholm

2014


LOCATION DIAGRAM

EXPLANATION

The shape and elevation of the bedrock surface in Morrison County were determined from records of water wells and scientific drill holes (including holes drilled for this project), passive seismic soundings, and mapped outcrops. At a given location, the user should 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. Those areas with a high density of bedrock control points are likely to have accurate interpretations of the bedrock elevation, whereas those areas with widely-spaced control points may be less reliable and inappropriate for site-specific needs. Of the three data types available, the outcrops are regarded as the most reliable, drill holes—especially scientific 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 a 50-foot (15-meter) interval.

The bedrock surface is highest in the northeastern part of the county where it reaches 1,330 feet (405 meters) above sea level. It is lowest where a valley exits the southern border of the county at approximately 900 feet (274 meters) above sea level. The 430 feet (131 meters) of total relief on the bedrock surface is slightly less than the more than 500 feet (152 meters) of relief on the present land surface of the county. The highest point of the land surface is on hilltops in the northwestern part of the county that exceed 1,500 feet (457 meters) above sea level. The lowest point of the land surface is where the Mississippi River exits the county at about 1,015 feet (309 meters) above sea level. The largest feature of the bedrock surface is a north–south-trending valley that bisects the county slightly east of the Mississippi River. It is broad at the southern boundary of the county (about 12 miles [19 kilometers] across) and narrows to less than 3 miles (5 kilometers) across at the northern boundary. There is some inconsistency between seismic interpretations and well data about where the valley narrows, and the interpretations on this map may change as more data become available.

The present elevation of the bedrock surface is dependent upon several factors, mainly the resistance of the underlying bedrock to weathering and erosion, but also features such as faults, folds, and other bedrock structures. As a result, the bedrock topography exhibits some correlation with rock units. Those rock types that are most resistant to erosion typically tend to occupy higher parts of the topography and less resistant rock types are associated with low areas. The bedrock valley described above occurs in less resistant rock units and is bounded to the east by granitic rocks that are more resistant. In other areas erosion associated with glaciation was the dominant factor in shaping the bedrock surface and variation in the properties of the bedrock types appears to have been a less important factor.

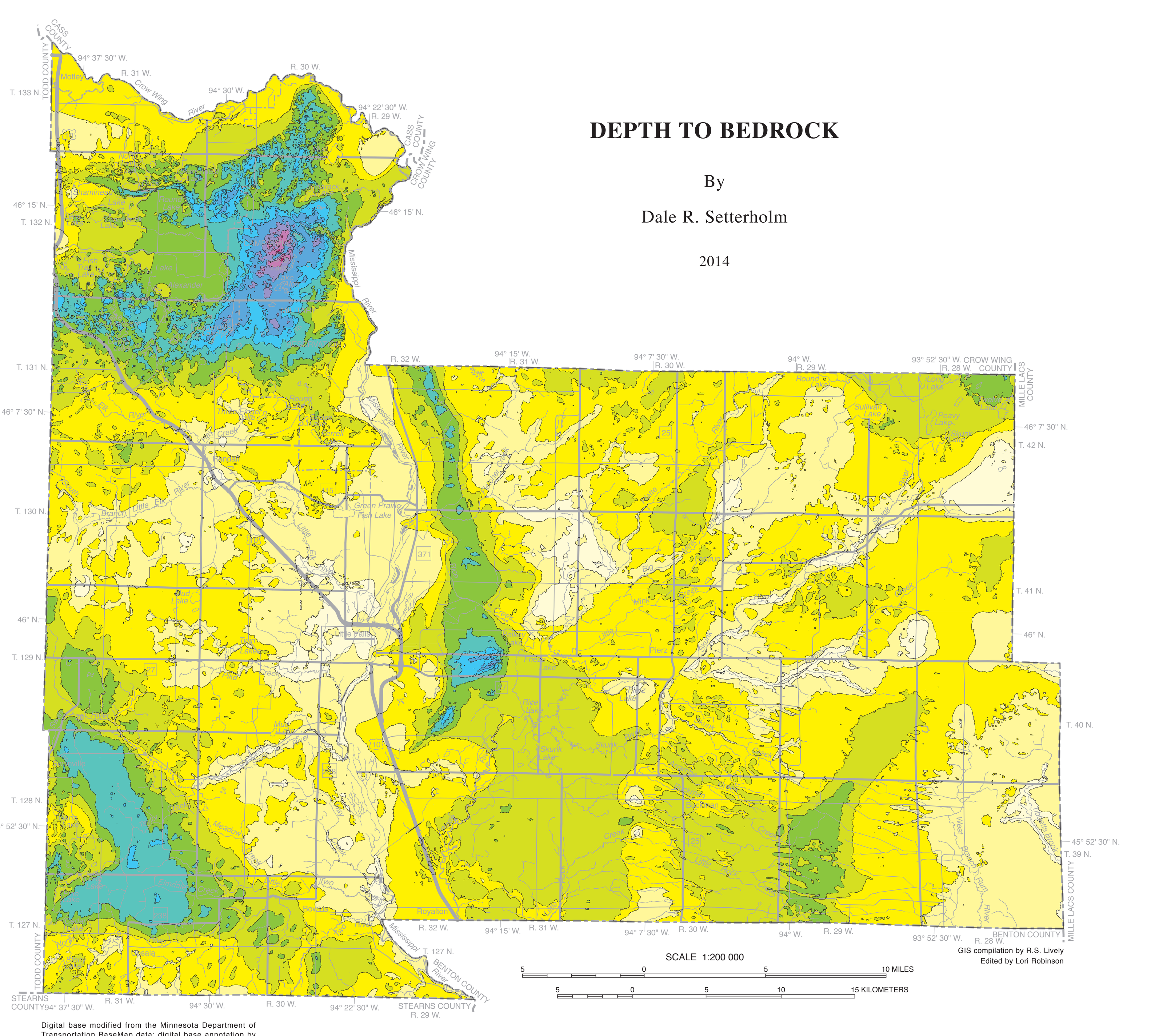
Elevation of the bedrock surface in feet above mean sea level

- 1,301-1,350
- 1,251-1,300
- 1,201-1,250
- 1,151-1,200
- 1,101-1,150
- 1,051-1,100
- 1,001-1,050
- 951-1,000
- 901-950

SCALE 1:200 000

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

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



DEPTH TO BEDROCK

By

Dale R. Setterholm

2014

EXPLANATION

The bedrock in Morrison County is mostly covered by glacial sediment that varies from a few feet to more than 350 feet (107 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*.

The thickness of the glacial sediment is equal to the depth from the land surface to the bedrock surface. To calculate that 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, illustrated on Plate 1, *Data-Base Map*, to comprehend 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 over short distances, and mapping at this scale may not provide sufficient detail.

The glacial thickness map is more detailed than the data support. This 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.

The thickest glacial sediment occurs in the northwestern part of the county, where the bedrock surface is moderately low, and the land surface is very high. The thinnest glacial cover correlates with areas where the bedrock is exposed at the surface. The glacial sediment is also generally thinner where rivers and streams have eroded into the glacial materials.

Depth in feet from the land surface to the bedrock surface

- 1–50
- 51–100
- 101–150
- 151–200
- 201–250
- 251–300
- 301–350
- 351–400
- 401–450
- 451–500
- 501–550

SCALE 1:200 000

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

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

SAND DISTRIBUTION MODEL

By

Barbara A. Lusardi and Jacqueline Hamilton

2014

INTRODUCTION

The Quaternary sand and gravel deposits of Minnesota are products of a long and complex history of multiple glacial events that makes mapping of these potential aquifer-bearing units difficult. However, establishing the location and characteristics of sand and gravel aquifers is an essential step toward their use and protection. The Morrison County atlas project included the expertise of a geologist and a geographic information system (GIS) specialist. GIS was used to create three-dimensional models that show the distribution of the Quaternary sand and gravel deposits, which are commonly aquifers. The geologist interprets the three-dimensional models and relates aquifers to the glacial events that formed them. Although the models and interpretations are based on the best available data, they are unavoidably incomplete due to a lack of data in some areas (see Plate 1, *Data-Base Map*).

Surficial sand and gravel deposits are mapped using primary data from exposures, shallow drill holes, soil maps, and landforms. In contrast, buried sand and gravel deposits are mapped using well records, scientific drill core, and drill cuttings—data which may be sparser and less accurate than the data used in surficial mapping. Therefore the unit extent, thickness, stratigraphic correlation, and even the matrix material of buried units are not as well constrained as for the surficial units.

The unconsolidated Quaternary sediments that overlie the bedrock in Morrison County vary greatly in character and thickness. These deposits are largely the result of many distinct glacial ice advances during the Pleistocene Epoch (Plate 3, *Surficial Geology*). Most of the aquifers within Morrison County consist of sand and gravel beds laid down by meltwater that flowed from these glaciers. Unsorted sediment deposited directly from the ice (till) and clay- and silt-rich bedded sediment deposited in ponded meltwater in front of the glaciers form confining layers that may enclose the aquifers. The till layers left by each ice sheet tend to be more laterally persistent than the sand layers because they are more cohesive and are deposited by ice that typically spread across the entire county. The sand and gravel deposited by meltwater streams are generally restricted to drainages at lower elevations of the evolving landscape. These deposits are easier to erode than till. Sand and gravel may be deposited by both an advancing glacier and a retreating glacier of the same cycle. Thus, till from an ice advance may bury its own sand and gravel, as well as material deposited during a previous glacial event. By convention, the name designations of sand and gravel bodies depicted in this report are associated with their underlying till (except for those at the land surface and those that intersect the lowermost unknown units; Plate 4, Fig. 5).

Glacial ice and meltwater not only deposited sediments, but also eroded older, underlying sediments, creating a very disturbed "layer cake" stratigraphy. A new layer of sand or till could fill a void eroded into an older layer or could completely take the place of an older layer, given sufficient erosion. The net effect of this depositional and erosional activity is that sand and gravel bodies that provide water to wells in Morrison County tend to be discontinuous. Even over relatively short distances in most directions, the extent and thickness of any given aquifer is difficult to predict. In order to create a valid geologic model of the subsurface, 67 closely spaced (0.6 mile [1 kilometer]) cross-section lines were generated in a west–east direction (Plate 4, Fig. 3). Along these lines, water-well records and records of scientific and engineering test holes (Plate 1, *Data-Base Map*) were used by a geologist to identify contacts between till units in the subsurface. Final interpretations along six of these cross sections are shown on Plate 4, *Quaternary Stratigraphy*.

Till is generally described as "clay" by well drillers. Although sand and gravel can occur within a till, more extensive deposits tend to occur at the contact between two till sheets. Where two clay (interpreted as till) layers related to different depositional events are not separated by a sand and gravel layer, their contact may be recognized by a change in the driller's description of the clay's texture, density, or color. Using the available data, contact lines between each geologic unit were drawn along each cross section. Each line represents the base of a unit of sand and gravel or till. GIS was used to extract elevation values from vertices along each unit line. Each vertex was then used to create a raster elevation surface showing the distribution of the unit over the county. The till and sand surfaces were edited until the geologist was confident that they adequately represented the stratigraphic interpretation for the majority of water-well data. When the till and sand surface rasters representing the base of each unit were final, they were processed through GIS raster calculations to create top and bottom surfaces for each geologic unit as well as a thickness for each sand unit. The result is a three-dimensional geologic model of tills and sands for the county. The more extensive sands are shown in Figures 1 through 14. The figures show sand units ranging from the youngest sands at the land surface to buried, progressively older sands (Plate 4, Fig. 5).

Where saturated, these sand bodies are aquifers. Their capacities for water yield depend on their extent and thickness, as well as factors such as sediment coarseness, degree of sorting, consolidation, and potential for recharge. In many places two or more of these sand units form a single aquifer where they are juxtaposed with no intervening till layer.

The geologic model should be considered a probability map for the occurrence and approximate thickness of major sand bodies. The model does not guarantee sand and gravel will be found at all places shown, nor does it preclude them from being found in areas where they are not shown. Sands that were too thin or did not extend to neighboring cross sections commonly were eliminated during processing. Because wells typically do not penetrate the complete thickness of sand layers, drillers' logs commonly under report sand-body thickness. As a result, some of the sands shown on the cross sections (Plate 4) may be thicker and more widespread than they are portrayed. At increasing depths in the stratigraphic section, data availability diminishes and delineated sand bodies could be more or less discontinuous than shown. Note that the east–west linearity of some sand bodies may be the product of modelling along east–west cross-section lines.

In many parts of Morrison County water wells do not extend through the full thickness of the Quaternary deposits. The cross sections indicate that the characteristics of deeper Pleistocene deposits cannot be differentiated in some places. However, where deep drill holes occur locally, thicker sands are commonly present. Additional sand bodies, or extensions of those mapped, are undoubtedly present in these undifferentiated parts of the Pleistocene section. In spite of these limitations, the geologic model provides a realistic interpretation of where and what kind of geologic units would be encountered in the subsurface of Morrison County. However, given the limits 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.

CONTOURS FOR FIGURES 1 THROUGH 14

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

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

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

DEPTH FOR FIGURES 2 THROUGH 14

- 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 14).

SCALE 1: 400 000

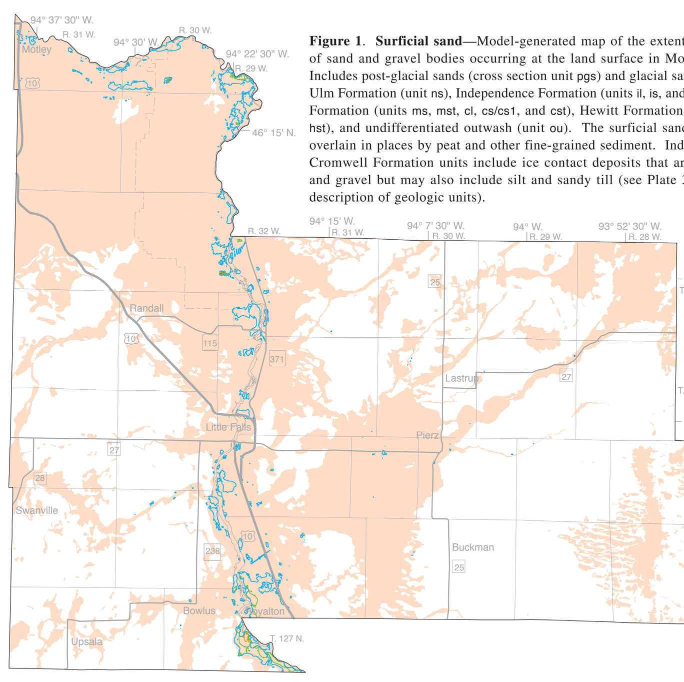


Figure 1. Surficial sand—Model-generated map of the extent and thickness of sand and gravel bodies occurring at the land surface in Morrison County. Includes post-glacial sands (cross section unit pgs) and glacial sands of the New Ulm Formation (unit ns), Independence Formation (units il, is, and ist), Cromwell Formation (units ms, mst, cl, cs/cs1, and cst), Hewitt Formation (units hss and hst), and undifferentiated outwash (unit ou). The surficial sand and gravel is overlain in places by peat and other fine-grained sediment. Independence and Cromwell Formation units include ice contact deposits that are chiefly sand and gravel but may also include silt and sandy till (see Plate 3 for complete description of geologic units).

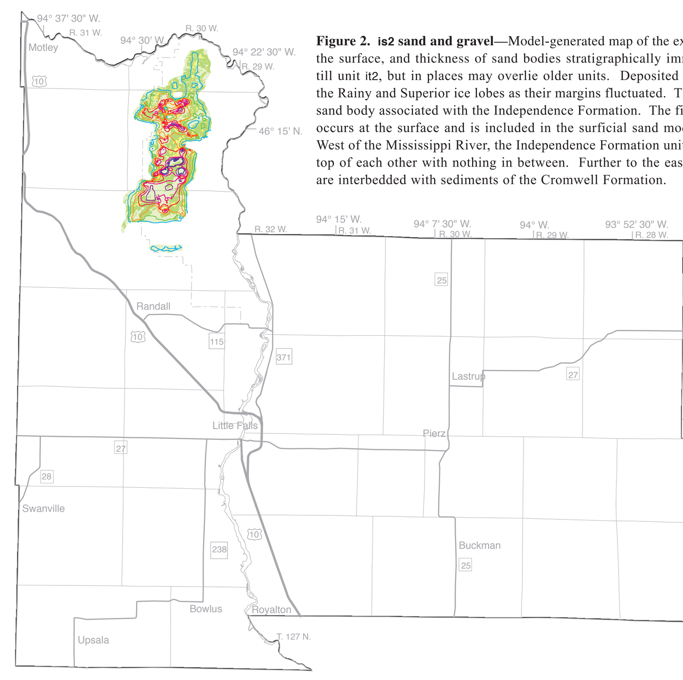


Figure 2. is2 sand and gravel—Model-generated map of the extent, depth from the surface, and thickness of sand bodies stratigraphically immediately above till unit it2, but in places may overlie older units. Deposited by meltwater of the Rainy and Superior ice lobes as their margins fluctuated. This is the second sand body associated with the Independence Formation. The first sand (unit is) occurs at the surface and is included in the surficial sand model on Figure 1. West of the Mississippi River, the Independence Formation units are stacked on top of each other with nothing in between. Further to the east, however, they are interbedded with sediments of the Cromwell Formation.

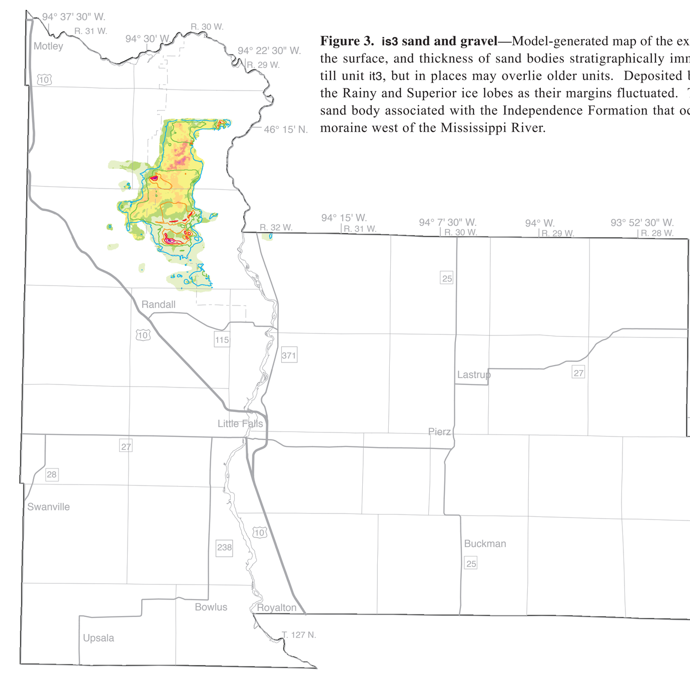


Figure 3. is3 sand and gravel—Model-generated map of the extent, depth from the surface, and thickness of sand bodies stratigraphically immediately above till unit it3, but in places may overlie older units. Deposited by meltwater of the Rainy and Superior ice lobes as their margins fluctuated. This is the third sand body associated with the Independence Formation that occurs within the moraine west of the Mississippi River.

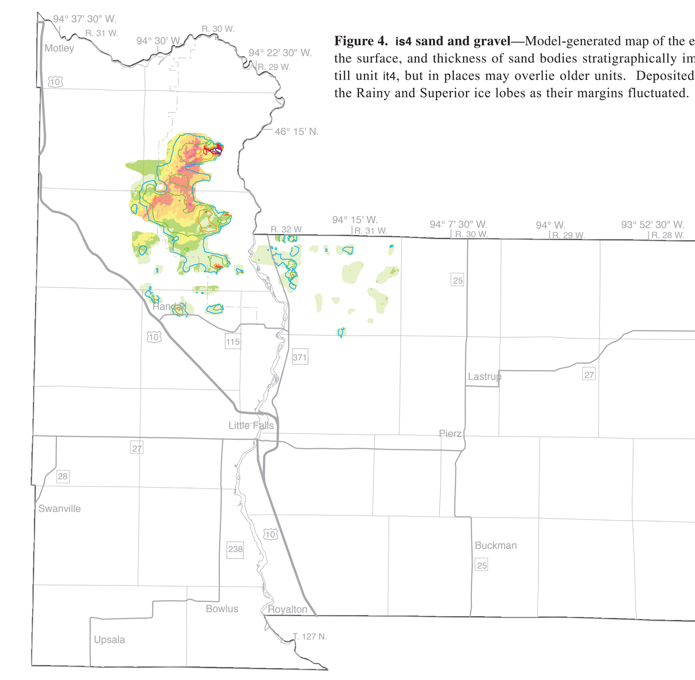


Figure 4. is4 sand and gravel—Model-generated map of the extent, depth from the surface, and thickness of sand bodies stratigraphically immediately above till unit it4, but in places may overlie older units. Deposited by meltwater of the Rainy and Superior ice lobes as their margins fluctuated.

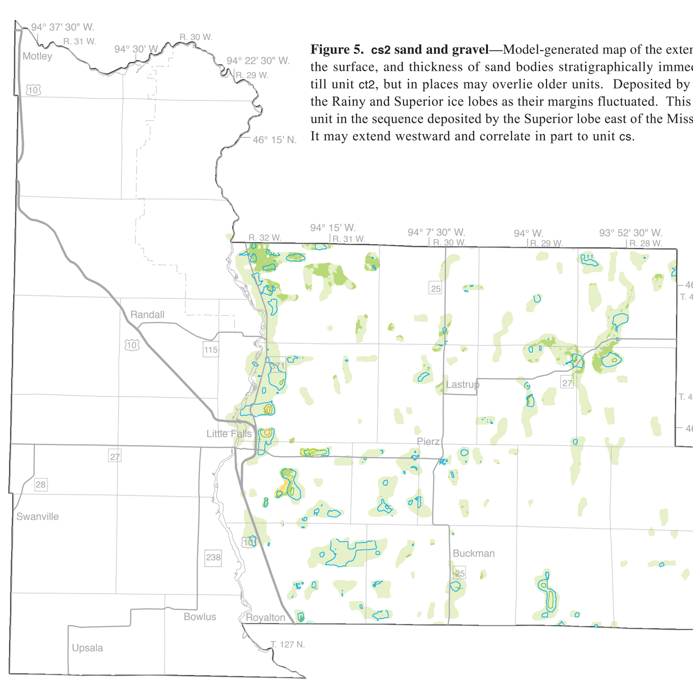


Figure 5. cs2 sand and gravel—Model-generated map of the extent, depth from the surface, and thickness of sand bodies stratigraphically immediately above till unit ct2, but in places may overlie older units. Deposited by meltwater of the Rainy and Superior ice lobes as their margins fluctuated. This is the second unit in the sequence deposited by the Superior lobe east of the Mississippi River. It may extend westward and correlate in part to unit cs.

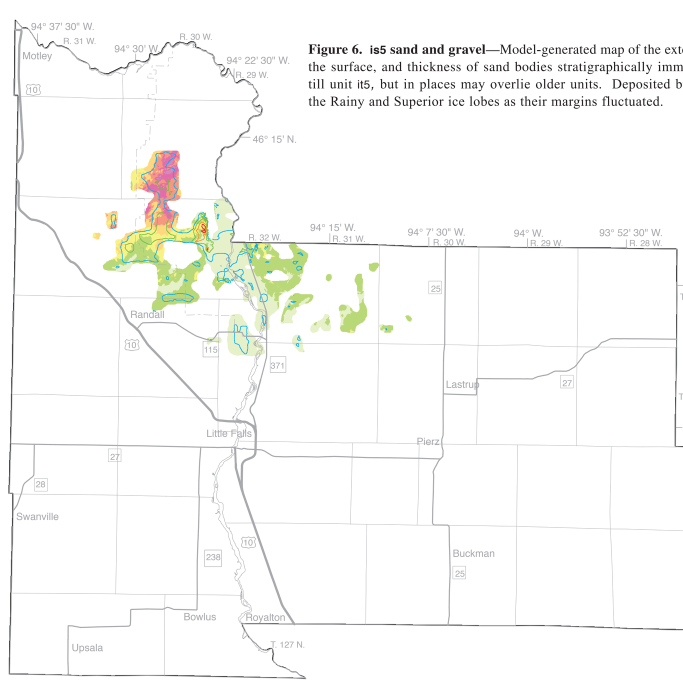


Figure 6. is5 sand and gravel—Model-generated map of the extent, depth from the surface, and thickness of sand bodies stratigraphically immediately above till unit it5, but in places may overlie older units. Deposited by meltwater of the Rainy and Superior ice lobes as their margins fluctuated.

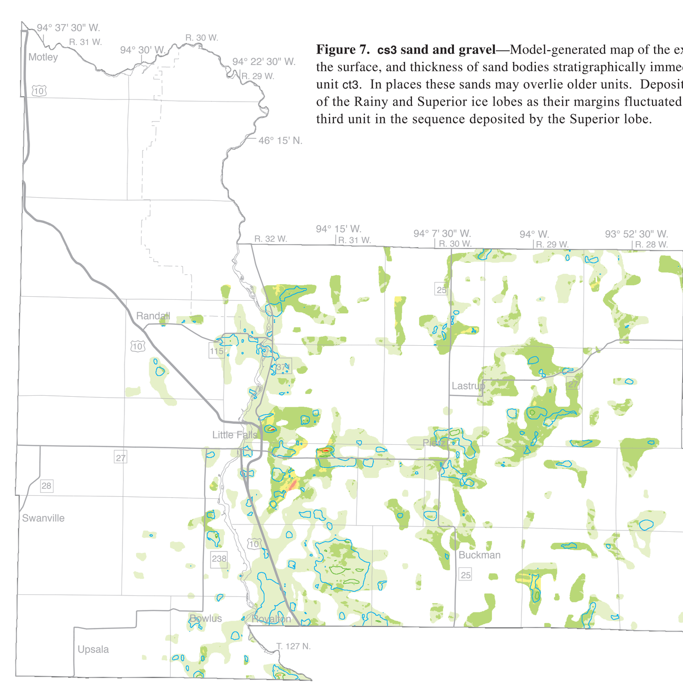


Figure 7. cs3 sand and gravel—Model-generated map of the extent, depth from the surface, and thickness of sand bodies stratigraphically immediately above till unit ct3. In places these sands may overlie older units. Deposited by meltwater of the Rainy and Superior ice lobes as their margins fluctuated. Unit cs3 is the third unit in the sequence deposited by the Superior lobe.

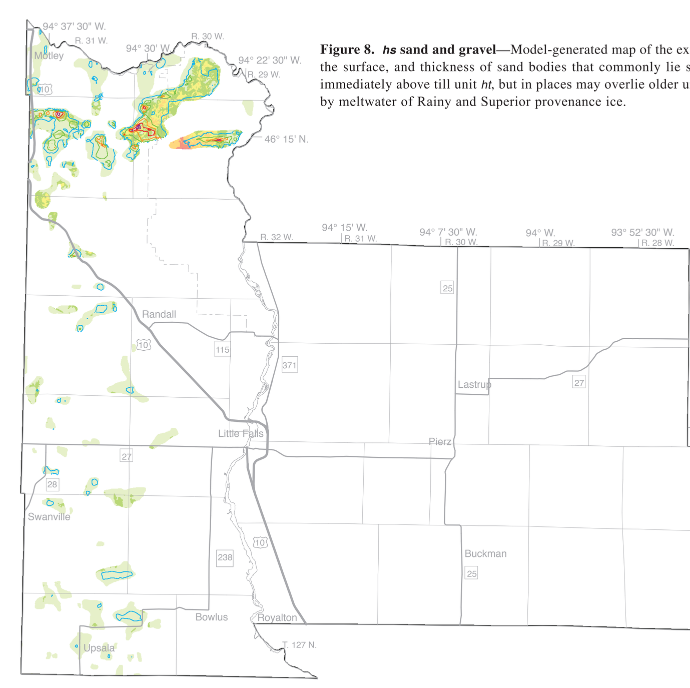


Figure 8. hs sand and gravel—Model-generated map of the extent, depth from the surface, and thickness of sand bodies that commonly lie stratigraphically immediately above till unit ht, but in places may overlie older units. Deposited by meltwater of Rainy and Superior provenance ice.

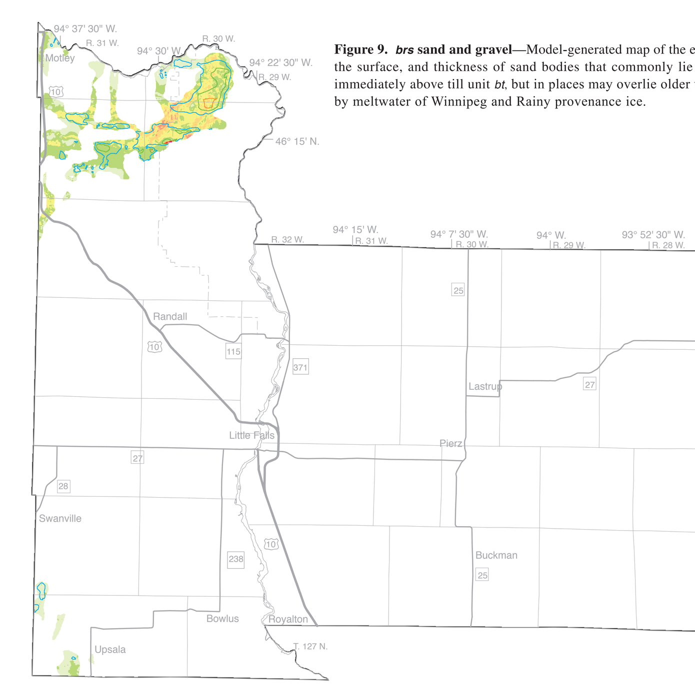


Figure 9. brs sand and gravel—Model-generated map of the extent, depth from the surface, and thickness of sand bodies that commonly lie stratigraphically immediately above till unit bt, but in places may overlie older units. Deposited by meltwater of Winnipeg and Rainy provenance ice.

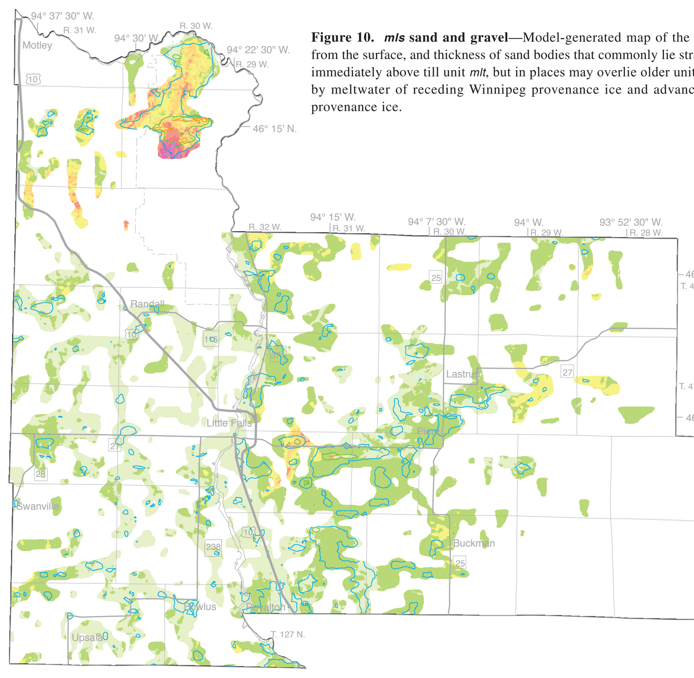


Figure 10. mls sand and gravel—Model-generated map of the extent, depth from the surface, and thickness of sand bodies that commonly lie stratigraphically immediately above till unit mlt, but in places may overlie older units. Deposited by meltwater of receding Winnipeg provenance ice and advancing Superior provenance ice.

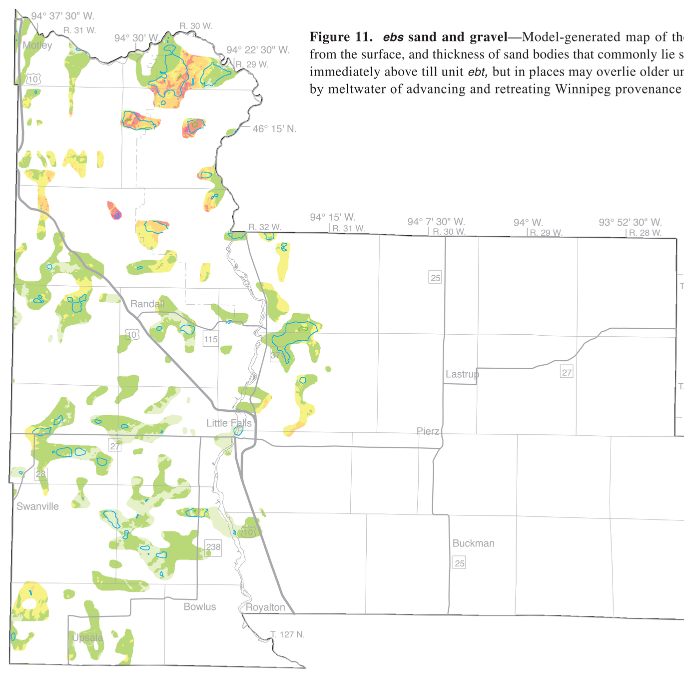


Figure 11. ebs sand and gravel—Model-generated map of the extent, depth from the surface, and thickness of sand bodies that commonly lie stratigraphically immediately above till unit ebt, but in places may overlie older units. Deposited by meltwater of advancing and retreating Winnipeg provenance ice.

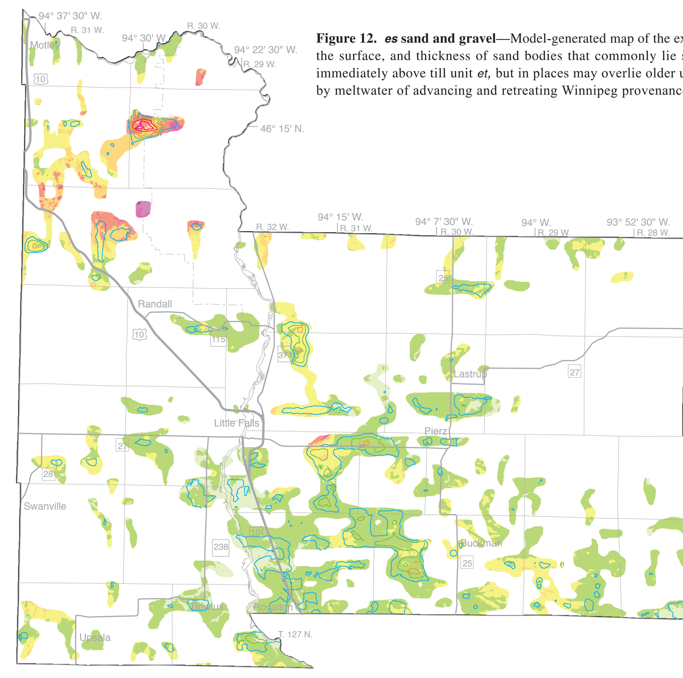


Figure 12. es sand and gravel—Model-generated map of the extent, depth from the surface, and thickness of sand bodies that commonly lie stratigraphically immediately above till unit et, but in places may overlie older units. Deposited by meltwater of advancing and retreating Winnipeg provenance ice.

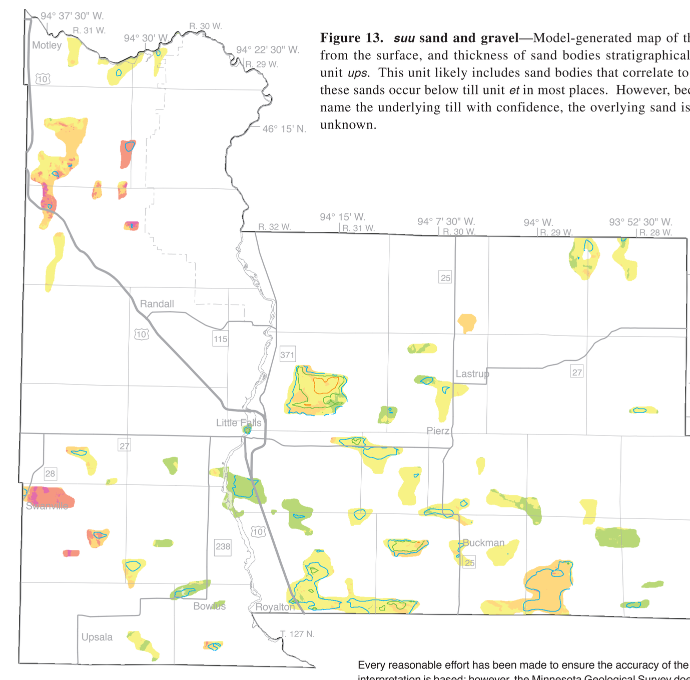


Figure 13. suu sand and gravel—Model-generated map of the extent, depth from the surface, and thickness of sand bodies stratigraphically at the top of unit ups. This unit likely includes sand bodies that correlate to unit vs because these sands occur below till unit et in most places. However, because we cannot name the underlying till with confidence, the overlying sand is also labeled as unknown.

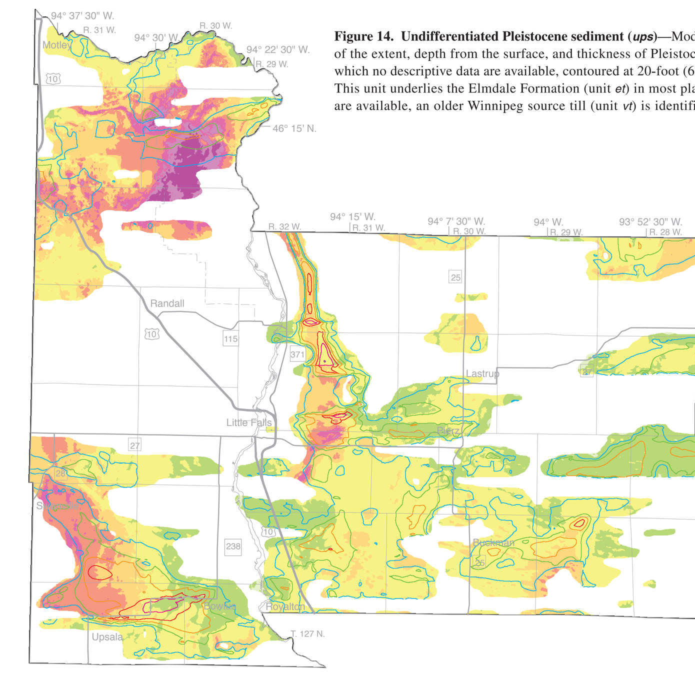


Figure 14. Undifferentiated Pleistocene sediment (ups)—Model-generated map of the extent, depth from the surface, and thickness of Pleistocene sediment for which no descriptive data are available, contoured at 20-foot (6-meter) intervals. This unit underlies the Elmdale Formation (unit et) in most places. Where data are available, an older Winnipeg source till (unit vt) is identified.