# DIGITAL MAPPING TECHNIQUES 2013

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# 3D Sand Modeling for Characterizing Aquifer and Aggregate Resources


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## Introduction

Establishing the distribution and thickness of sand and gravel deposits is an essential step toward the use and protection of groundwater resources. Also, near-surface sand and gravel bodies may be important as an aggregate resource. The structure and subsurface mapping process combines a variety of often limited data, geologic interpretation, and the data-handling capability of a geographic information system (GIS) to create three-dimensional (3D) models of sand and gravel bodies.

In glaciated terrain, multiple events of glacial deposition and erosion create unique problems in defining discrete stratigraphic units at the county level (100k) scale of mapping. The model results display a distribution of sands and gravels both at the surface and in the sub-surface. These models form the geologic framework that the Minnesota Geological Survey and other public and private entities use to identify and monitor aquifer and aggregate resources.

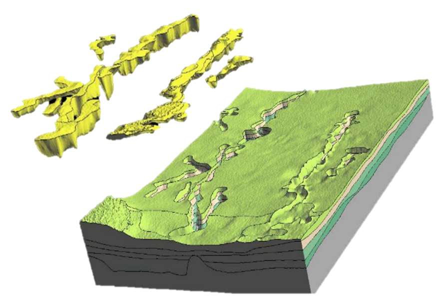
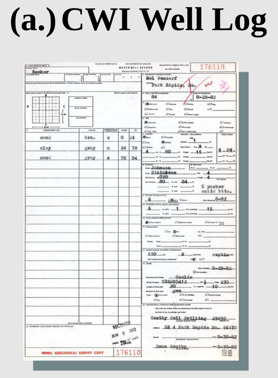


**Figure 1.** Modeling sand bodies in 3D to determine aquifer sensitivity to potential contamination.

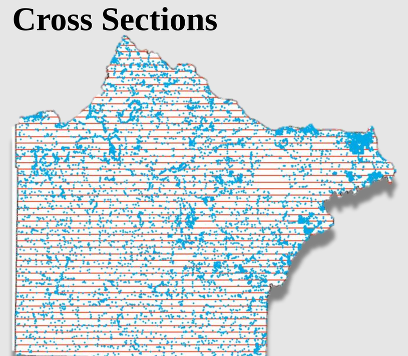
## Materials and methods

The creation of Minnesota's sand model stratigraphy is implemented through ESRI's ArcGIS. In order to model the subsurface, descriptions and samples from water well records, rotary-sonic core, scientific cutting sets, and auger borings (2a) are collected from the County Well Index (CWI) database. Closely spaced cross section lines are then generated in a west–east direction (2b). The geologist provides an interpretation of materials that occur in the areas between wells or at depths not penetrated by wells, based primarily on an understanding of geologic processes (2c). The distribution of data greatly affects the resolution and accuracy of the models.

**(a.) CWI Well Log**



**(b.) CWI Well Locations & Cross Sections**



Wright County

**(c.) Geologic Cross Section**

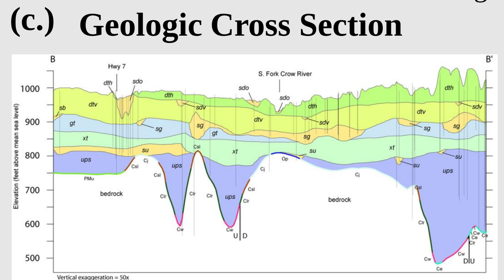
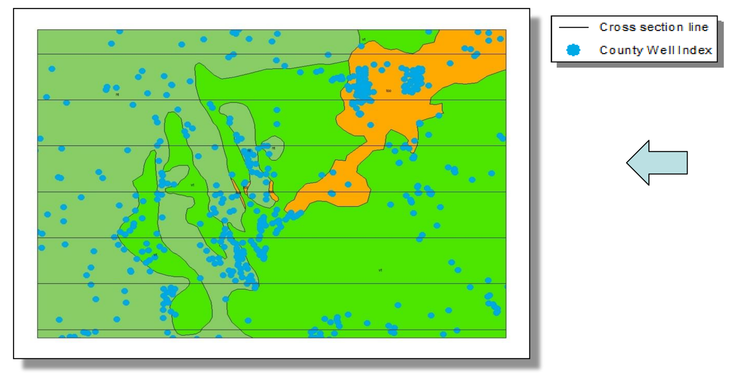


**Figure 2**. The existing CWI database is maintained by the Minnesota Geologic Survey and the Minnesota Department of Health (**a**). This database assists the geologists with creating cross sections across the county (**b, c**). Each cross section, spaced 1,000 meters, traverses the county in an east-west direction.

## Results

As our 3D modeling processes have evolved we have tried to improve gridding efficiency and accuracy for Minnesota's Wright County (in press). Specific sand and gravel units were pulled out for additional analysis. Glaciated terrain of sand bodies typically display varied thickness and can be discontinuous in many locations. The following steps yielded significant improvement in gridding accuracy relative to the geologists interpretation of the geologic structure of subsurface sand and gravel deposits.

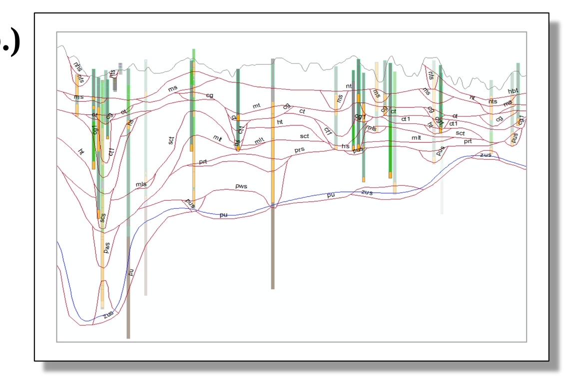
**(a.)**



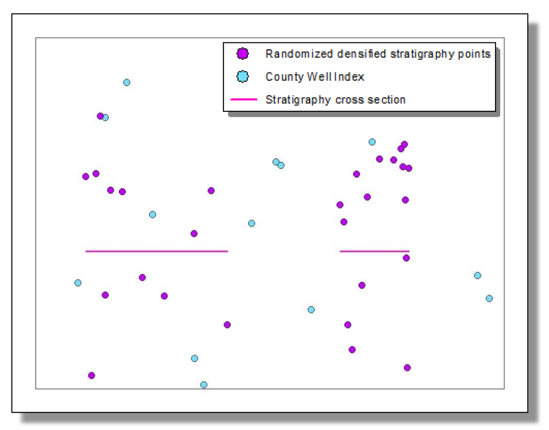

This displays the initial data (CWI locations and cross section location) that the geologist uses for the interpretation of the stratigraphy units.

**(b.)**

The geologist digitizes each unit based upon the CWI data. Locations, either bore holes or wells, are included if they fall within 500 meters of each cross section line. The CWI locations fade the further away they are from the cross section.



**(c.)**

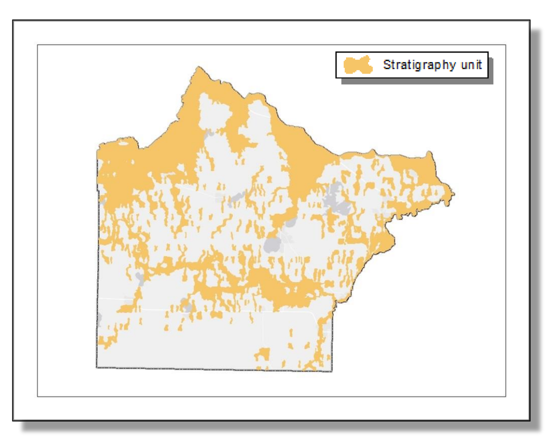



Stratigraphic layers are created by a geologist along each cross section. Python scripts are used to extract the layers and plot their projections into a mapview. Additional elevation points from each cross section layer are then randomly distributed north and south of the cross section line to provide additional elevations for the gridding process.

**(d.)**

A geologists then draws a boundary (mask) around the points defining the extent of the stratigraphic unit.


**(e.)**



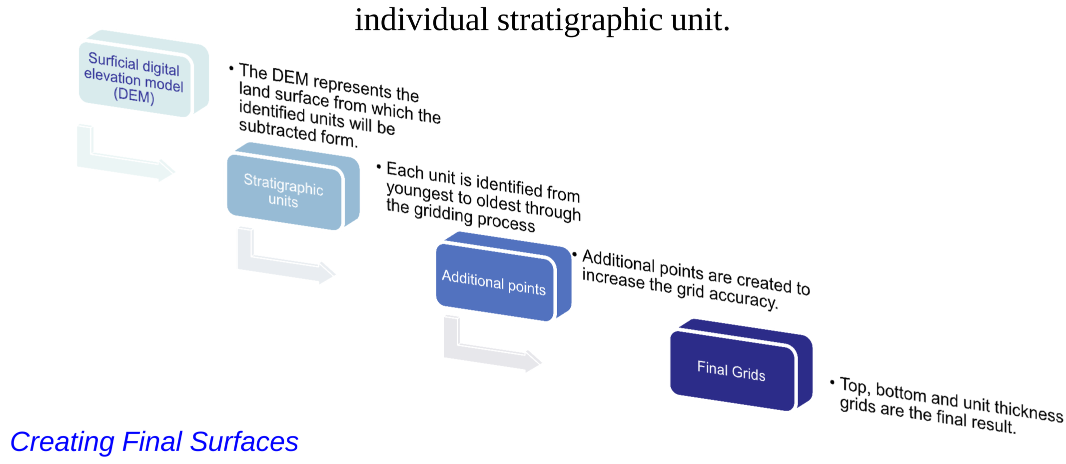

The final results show a single stratigraphic unit extent within the county.

**Figure 3.** The process of creating 3D stratigraphic units within a county between the land surface and bedrock surface.

In Wright County, the subsurface model was created using 10,868 CWI records and 50 closely spaced cross section lines. The process of moving from 2D cross sections to a 3D model (**Figs. 3a,b,c ,d and e**) requires close communication and coordination between the geologist and GIS specialist. Wright County contains approximately 28 stratigraphic Quaternary units of which there are 14 sand and gravel deposits. Figure 3e displays just one of the 14 units.

*Creating Working Surfaces*

With the use of ESRI's Spatial Analyst, 3D Analyst and Python scripts we can begin to create grids for each individual stratigraphic unit.




*Creating Final Surfaces*

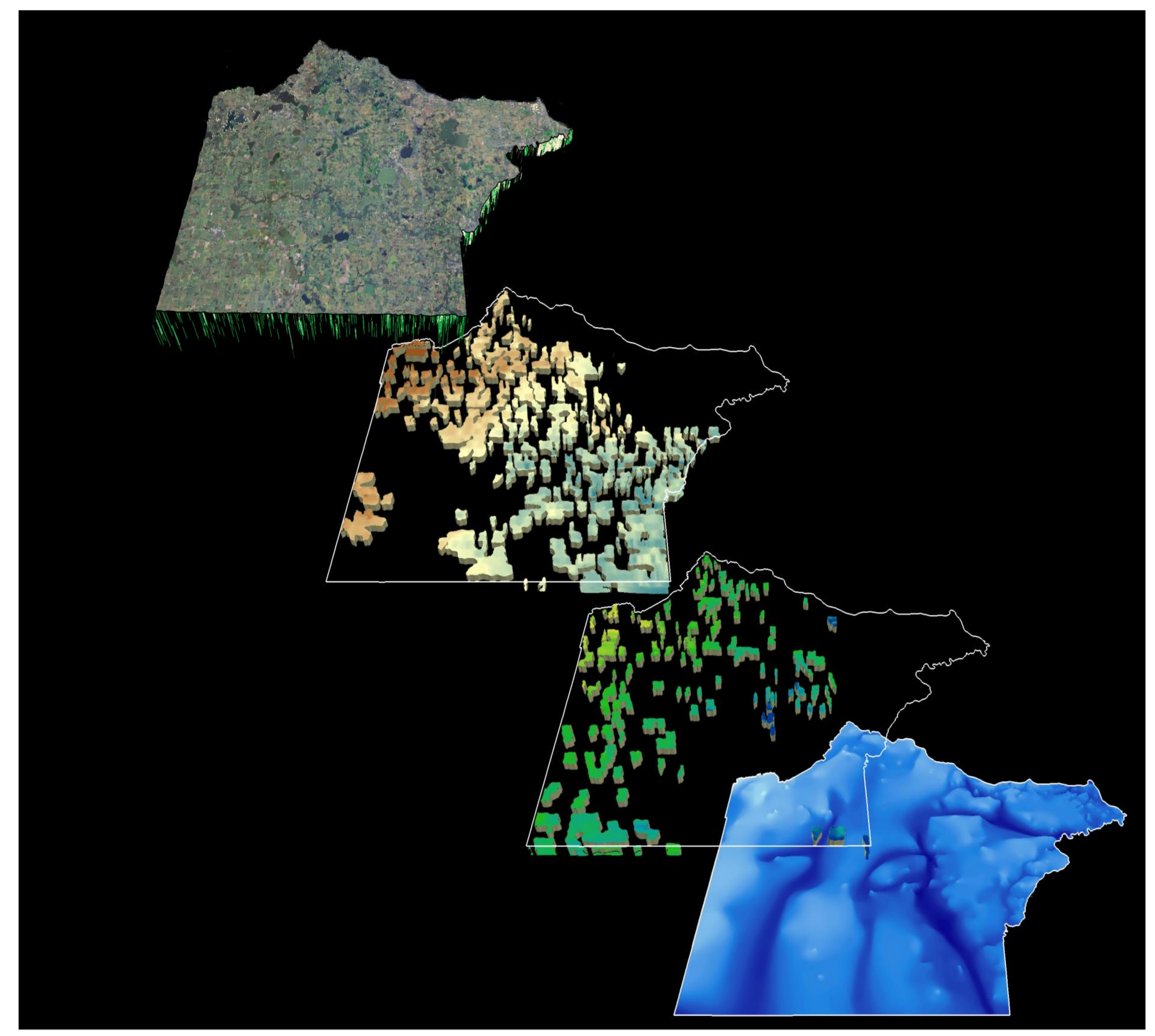


**Figure 4.** Four grids representing the surface elevation with wells, two (out of 14) stratigraphic sand unit grids and the bedrock elevation grid.

*Checking grid surface against the geologists cross sections for accuracy.*

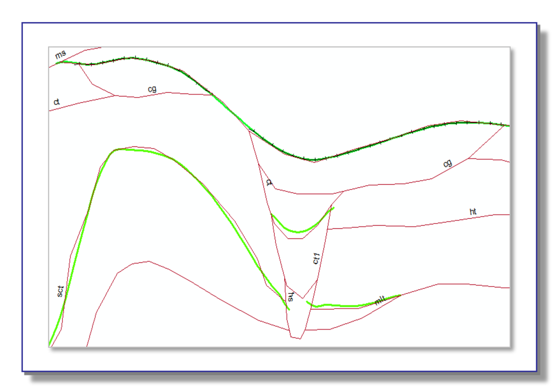


**Figure 5.** Final grid elevation for a bottom unit (shown in green hatched line) along with the original geologic cross section (shown in red).

Profiles of the final grid tops and bottoms of each unit can be checked against the original geologic cross section. This is used to identify any gridding errors and pin point specific locations for making corrections.

## Conclusions

The use of 3D technology for geologic mapping is on the rise. The efficiency and cost effectiveness of these methods have increased the rate at which we can produce subsurface models. Minnesota is one of many states that contain glaciated terrain which provide a unique set of problems and complexities when it comes to mapping individual stratigraphic units. Many of the mapping technologies today allow the geologist to construct 3D models that closely match their particular geologic interpretation of the subsurface.

The Minnesota Geological Survey has been using ESRI's ArcMap software to model the glacial terrain at a county scale. Individual stratigraphic units can be modeled separately. The addition of randomized points, as well as additional points along the mask outlines for each stratigraphic unit, increases the accuracy and look of the grid for each unit. For Wright County, the modeling results display a distribution of mappable sand and gravel units, both at the surface and sub-surface.

Increasing the accuracy of 3D modeling improves the understanding of our geologic resources. These refined 3D models form the geologic framework that the Minnesota Geological Survey and other public and private entities use to identify and monitor important aquifer and aggregate resources.

## References Sited


Berg, R.C. and Mathers, S.J. and Kessler, H. and Keefer, D.A., 2011. Synopsis of current three-dimensional geological mapping and modeling in geological survey organizations. *Illinois State Geological Survey and British Geological Survey*, Circular 578.

County Well Index, State Water Well Database, Minnesota Geological Survey, Minnesota Department of Health, http://www.health.state.mn.us/divs/eh/cwi.

Lusardi, B.A. and Tipping, R.G., 2009, Sand Distribution Model, pl. 4 of Bauer, E.J., project manager, Geologic atlas of Carver County, Minnesota: *Minnesota Geological Survey County Atlas C-21*, 5 pls., scale 1:100,000.

Lusardi, B.A. and Lively, R.S., 2009, Sand Distribution Model, pl. 5 of Lusardi, B.A., project manager, Geologic atlas of McLeod County, *Minnesota: Minnesota Geological Survey County Atlas C-20*, 6 pls., scale 1:100,000

Meyer, G.N., Tipping, R.G., and Lively, R.S., 2013, Sand Distribution Model, pl. 5 of Meyer, R.N., project manager, Geologic atlas of Anoka County, *Minnesota: Minnesota Geological Survey County Atlas C-27*, 6 pls., scale 1:100,000.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## For further information


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