Construction of a geological model of the Winnipeg region for groundwater modeling

Thorleifson, L.H.¹, G. L. D. Matile², D. M. Pyne¹, and G. R. Keller²
¹Geological Survey of Canada, 601 Booth Street, Ottawa, ON K1A 0E8; ²Manitoba Geological Survey, 1395 Ellice Avenue, Winnipeg MB R3G 3P2

Nearly all of the one million inhabitants of the Province of Manitoba, Canada, live in the 400-km x 700-km area of Phanerozoic terrane in the southern portion of the province, adjacent to North Dakota and Minnesota. The majority live in the Winnipeg area, a 200 km x 230 km area in the southeastern corner of the province. The City of Winnipeg obtains water from Shoal Lake, but the 200,000 residents of surrounding areas rely on groundwater obtained from bedrock aquifers. Fresh water in these aquifers consists of modern recharge and relict subglacial recharge, but a saline water system recharged in South Dakota and Montana discharges to the western Red River valley. Research on the long-term sustainability of the fresh groundwater resource is addressing protection of recharge, and ensuring that excessive pumping does not lead to unacceptable lateral migration of the saline waters. Modeling is a key element of this strategy, and a geological model was required. The model was built as follows:

**Topography:** Having found readily available models to be inadequate, a new model was constructed by the authors, largely from Provincial legal survey data. The resulting model has a grid resolution of 100 m, absolute vertical accuracy of about +/- 3 m, and relative accuracy in tenths of a metre. The data have been used to position drill holes vertically, the geological model hangs from the topography, and the model has provided insight into previously unrecognized geological features.

**Bathymetry:** Large lakes occur in the area, including Lake Winnipeg, which is 25% larger than Lake Ontario. These are key features in the hydrogeological landscape, and lake-bottom features provide insights into geology. Soundings from 22 hydrographic charts therefore were digitized and a database containing 31,607 digitized bathymetry points was created. These were modeled with shoreline data and locations of shoals, at a grid resolution of 100 m.

**Surficial geology:** Subsurface modeling was guided by the most detailed available surficial geological mapping. At this stage, the subsurface model is not linked to the polygons, due to the much greater detail of the surficial geological mapping, relative to the resolution that could be achieved in the subsurface.

**Quaternary stratigraphy:** Key inputs to the 3D model of the sediments were cored holes logged by geologists, and geophysical surveys. These high-quality results were extrapolated laterally using water well data from 80,000 sites (Figure 1). Much effort was required to parse the 75,000 unique lithological descriptions in this database, and the results were interpreted using a scatterplot approach (Figure 2). The 200 km x 230 km Winnipeg area was divided into 46 strips each 5 km wide, and a large colour chart was printed for each strip, showing all drillhole data, surficial geology, and surface elevation. The drillhole data, colour-coded for lithology, were interpreted as a series of vertical maps (Figure 3), using the same methods used to compile plan-view maps. The interpretation was captured at 5 km spacing, and gridded.

**Bedrock geology:** A new set of 1:1 million bedrock polygons for the Phanerozoic units was constructed, linking outcrop to subcrop, to produce stacked polygons.
Phanerozoic stratigraphy: Structure contours for each Phanerozoic unit were gridded.

Figure 1. Location of water well data in southern Manitoba.
Figure 2. A portion of the drillhole data scatterplot for the 5 km swath shown in Figure 3; vertical scale in m asl, horizontal scale 75 km.
Figure 3. One of the 46 interpreted sections for the Winnipeg area.