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Groundwater Resources Studies

The *Groundwater Resources Study* (GRS) series seeks to better the understanding of Ontario's groundwater resources through the collection, evaluation and distribution of geoscience data. The main objective of the series is to provide accurate information on a range of groundwater-related themes, including local- to watershed-scale aquifer characterization and delineation; geologic controls and influences on groundwater quantity and quality; and methods development. Products of the groundwater program include geoscience reports, data sets and protocols for information collection and handling. Geoscience information generated through the series will find application in the protection and sustainable management of the province's groundwater resources.

Groundwater Resources Study 11

Three-Dimensional Modelling of Surficial Deposits in the Barrie–Oro Moraine Area of Southern Ontario

by A.K. Burt and J.E.P. Dodge

Groundwater Resources Study 11 can be downloaded from
http://www.geologyontario.mndmf.gov.on.ca/mndmaccess/mndm_dir.asp?type=pub&id=GRS011

This digital data release contains information regarding the three-dimensional distribution and character of surficial materials that form groundwater aquifers and aquitards within the Barrie–Oro Moraine area of southern Ontario. The data sets are organized into a series of folders, each containing information of varying type and format. These data include 1) a summary report (*.pdf*); 2) ESRI® ArcInfo® grids and comma-delimited (*.csv*) files of modelled surfaces; 3) Google Earth™ mapping service (*.kml*, *.kmz*) and portable network graphics (*.png*) files depicting borehole location and stratigraphic information as well as isopach and structural contour maps of modelled units; 4) graphic (*.jpg*) borehole logs; 5) analytical data (*.xls*) for samples collected; 6) high-resolution plates (*.pdf*) depicting north-south and east-west cross sections and structural contour and isopach maps; and 7) an abridged version of the subsurface data (*.mdb*) used for the construction of the three-dimensional block model, which includes borehole location, stratigraphic information and picks data. The data are available on 1 DVD.

A movie file (*Waterloo.avi*) from the Waterloo Region project (Bajc and Shirota 2007) showing the use of the Google Earth™ mapping service (*.kmz*) is also included. The 9 folders are listed as follows and are described below:

- Analytical Data – laboratory grain size and carbonate analysis results
- ArcInfo_Grids – ESRI® ArcInfo® grids of modelled surfaces
- CSV Files – comma-delimited (*.csv*) files of modelled surfaces
- Google Earth – Google Earth™ mapping service (*.kml*, *.kmz*) and portable network graphics (*.png*) files depicting borehole location and stratigraphic information as well as isopach and structural contour maps of modelled units
- Graphic Borehole Logs– revised graphic logs
- Plates – high-resolution plates depicting cross-sections and structural contour and isopach maps
- Report – the digital version of this report
- Subsurface Data – data set used to construct the 3-D block model including location, formation and picks tables

Analytical Data

This folder contains the results of laboratory chittick and grain size analyses.

CHITTICK DATA

Chittick analysis was done on 342 diamicton and fine-textured glaciolacustrine samples taken from cores drilled in 2004, 2005 and 2006. The results of these analyses were released previously in Miscellaneous Release—Data (MRD) 198 (Burt and Russell 2006) and MRD 227 (Burt 2007), but have also been included in this release. The first few columns (highlighted grey) identify the borehole and sample number and the sample depth. The next columns present the total percent of carbonate (highlighted in yellow) and a breakdown of the percent of calcite and dolomite (highlighted in blue). The final column of data is the ratio of calcite to dolomite (highlighted in green). This information can be used to further characterize the study area tills.

GRAIN SIZE DATA

Grain size analysis was done on 1578 samples taken from cores drilled in 2004, 2005 and 2006. The results of these analyses were released previously in MRD 198 (Burt and Russell 2006) and MRD 227 (Burt 2007). It was later determined that the clay content of the samples was underreported. Improvements have been made to the laboratory sample preparation and analytical procedures and 863 samples have been re-analyzed. Samples were selected for re-analysis where field descriptions indicated a clay and/or silt component. In the case of sand and gravel, the original results have been retained as testing indicated little or no change. The new grain size analytical results have been integrated with the retained original results and are presented in a single file on this release. The data are presented in a series of 3 Microsoft® Excel® worksheets listed and explained below.

Complete Data Set ("Data")

The complete data set reports the results of 1899 retained original and new grain size analyses, including quality-control duplicate samples and standards, integrated into a single data file. Duplicate samples are noted by the letter D in the sample number. One standard (sample number PSA B-#1) was used throughout. The first few columns (highlighted grey) identify the borehole and sample number, the sample depth and whether the analysis is part of original set of results (coded "original") or part of the re-analysis (coded "redo"). The sample identification information is followed by 2 sets of percent sand, silt and clay data. The first set is a summary (highlighted in yellow) and the second set (highlighted in blue) breaks the sand and silt down into very coarse-, coarse-, medium-, fine- and very fine-textured fractions. The next set of columns (highlighted in pink) report the particle size in micrometres (μm) at various percentiles. The reporting increments, as noted below, are slightly different for the original and new data. Next are some statistical data obtained directly from the particle size analyzer (highlighted in green). There are 3 mean particle diameter values, each calculated slightly differently, reported for each sample. What is important is that the mean volume diameter is weighted toward coarser textured particles resulting in a larger number, the mean number diameter is weighted toward finer textured particles resulting in a smaller number and the mean area diameter is somewhere in between. The

standard deviation simply gives the width of the measured particle size distribution. The final 2 sets of columns, percent in channel and percent passing, report the raw data from the particle size analyzer. The column headings give the particle size in micrometres (µm). Once again, the original and new data sets had slightly different reporting increments. This information should be used to more fully characterize the nature of the modelled aquifers and aquitards.

Quality Control Data ("QC")

This data set includes results for laboratory duplicate pairs from both the original and new data sets as well as the results for the laboratory standard. This information should be used to evaluate the reproducibility of results.

Reporting Increments ("Increments")

Slight changes have been made in the particle size analyzer reporting increments since the first set of samples were run. These changes are very small and so the decision was made to simply round off the reporting increments and present all the data in a single column. For example, data from the reporting interval of 2816 µm (2.816 mm) has been combined with data from the reporting interval of 2830 µm (2.830 mm) and presented under the heading of 2830 µm. The original and new reporting increments are presented in this table. Also included are lists of the original and new percentile reporting increments. In this case, the increment changes were much greater and so the data could not be combined.

ArcInfo_Grids

This folder contains 100 m ESRI® ArcInfo® structural contour grids for the 22 hydrostratigraphic units (a grid has not been prepared for the modern lakes). The grids are presented as discontinuous units (i.e., data exist only where the units have been modelled to occur).

CSV Files

This folder consists of 2 comma-delimited (*.csv*) files that contain information describing the elevation of the upper surface of the 23 hydrostratigraphic units on a 100 m grid. The "Discontinuous Surfaces" file can be used to produce surfaces that are a true representation of the distribution of the 23 hydrostratigraphic units modelled (i.e., elevation information occurs only where the units are present). The "Continuous Surfaces" file presents the 23 units as continuous surfaces across the entire region (i.e., where a particular unit is not present, it is assigned the elevation of the next older unit). These data are most useful for hydrogeologic modelling where continuous surfaces are required.

The centre point of each cell in the 100 m grid is identified in the columns XPT and XC (UTM easting, metres) and YPT and YC (UTM northing, metres) in the files "Continuous Surfaces" and "Discontinuous Surfaces", respectively. The elevation of the upper surface of each unit in metres above sea level (m asl) is given in the column ZPT and ZTOP, the stratigraphic sequence number of each unit (1 is youngest and 23 is oldest) is identified in column SEQNUM and the coded name of each unit in column STRATUM. The final column, THICK, contains the thickness of each unit. Note that the thickness of the Precambrian bedrock unit is NOT the true thickness of the basement rock, but rather the thickness above the base of the model.

Google Earth

Google Earth™ mapping service ("Google Earth™") is a free geographic viewing tool from Google Inc. (download from http://earth.google.com/). Google Earth™ offers very useful features for viewing and publishing geoscience data. Most of these features are exposed through an extensible markup language called keyhole markup language (*.kml*) or its compressed format (keyhole markup language–zipped (*.kmz*). This folder contains a Google Earth™ file (*Barrie.kml*) depicting the borehole locations used for the creation of the block model as well as the isopach and structural contour images for 22 hydrostratigraphic units (a surface has not been prepared for the modern lakes). By left clicking on a point representing a borehole location, a written log of the borehole including its source and type appears. The isopach and structural contour maps are represented as overlays with adjustable transparency allowing one to determine the spatial relationship of the various modelled units to other layers of information, such as bedrock and surficial geology.

Graphic Borehole Logs

This folder contains new borehole logs for the 32 continuously cored holes drilled in 2004, 2005 and 2006. Each log contains the following information, presented in a graphic (*.jpg*) format:

- Depth — depth below ground surface in metres
- Detail Lithologic Log — the width and colour of each segment corresponds to the primary material type
- Hydrostratigraphic Unit (text) — this column identifies the hydrostratigraphic unit each portion of the detailed log belongs to
- Unit Class — the intervals in this column are the same as the hydrostratigraphic unit column, but have been coloured according to their aquifer/potential aquifer – aquitard class. This can be considered a very basic prediction of the sediments anticipated for each hydrostratigraphic unit; aquifers/potential aquifers are dominantly sand and gravel, aquitards are dominantly till, clay and silt
- Grain Size — the length of each coloured bar represents the percent of clay, silt and sand for each sample analyzed including both original and new data sets
- Total Carbonate — the length of the bar represents the total percent of carbonate in each sample
- Ca/Do Ratio — the length of the bar represents the ratio between calcium carbonate (limestone) and magnesium carbonate (dolomite)
- Recovery — the length of each bar provides an estimate of the amount of material recovered in each core drilled as part of the 2005 and 2006 drilling programs

Plates

This folder contains 9 high-resolution digital (*.pdf)* versions of Plates 1 to 7. Plates 1 to 4 depict 25 west-east and 17 north-south cross sections spaced at 2.0 km intervals and coloured using the hydrostratigraphic and aquifer/potential aquifer – aquitard legends. The west-east cross sections have been split onto 2 sheets to make them easier to handle. Each plate includes a map of surficial sediments (coloured using the hydrostratigraphic legend) overlain with a grid that is to be used to identify the location of individual cross sections. The vertical lines are labelled 1 to 17 and correspond with the north-south cross-section numbers located along the left side of Plates 2 and 4. Select numbers are also shown across the top of the west-east cross sections where they provide an indication of distance along the cross section. The horizontal lines are labelled A to Y and correspond with the west-east cross-section letters located along the left side of Plates 1 and 3. Selected letters are shown across the top of the north-south cross sections. Plates 5 to 7 depict compilations of structural contour maps, isopach maps and maps of the picks used to generate each hydrostratigraphic unit. The structural contour and picks map plates have a map for each of the 23 hydrostratigraphic units displayed in order from youngest to oldest. The isopach plate does not contain maps for the Paleozoic and Precambrian units as thickness information is not meaningful for these units. These plates are also included at the end of the report.

Report

This folder contains a geological report (*.pdf* file) that describes the geology of the Barrie–Oro Moraine study area, the protocols established for three-dimensional modelling of the aquifers and aquitards and a brief description and interpretation of the main hydrostratigraphic units mapped within the area. Applications of the model are highlighted using examples that illustrate aquifer recharge areas and areas where aquifers are more vulnerable to sources of surface contamination. The report is best viewed using Adobe® Acrobat® Reader® version 7.0 or higher.

Subsurface Data[1]

This folder contains the Barrie–Oro Moraine area subsurface database (*Records.mdb*) in a Microsoft® Access® 2000 format. The following tables are present in the database.

Formation Table

The Formation Table contains 31 646 records and is an abridged version of the full modelling formation table. It includes the following fields:

- BHID — an internal 8-character MNDMF identification code used to link the tables in the subsurface database
- From (m) — the top of the formation in metres below ground surface
- To (m) — the bottom of the formation in metres below ground surface
- Layer — the formation number where 1 denotes the top (youngest) formation and n denotes the bottom (oldest) formation
- Lithology (translated) — this field contains the translated material type according to the 16 material classification scheme used for this project
- Original materials — where populated, this field contains sediment descriptors retained from the original data source
- Colour — where populated, the colour of the material from the original source

Location Table

The Location table contains 7155 records and is an abridged version of the full modelling formation table. It includes the following fields:

- BHID — an internal 8-character MNDMF identification code used to link the tables in the subsurface database
- X (NAD 83) — the UTM easting co-ordinate in NAD83, Zone 17
- Y (NAD 83) — the UTM northing co-ordinate in NAD8, Zone 17
- Z (masl) — the ground surface elevation in metres asl obtained from the MNR DEM
- Type of boring — designates the method of excavation or type of record (e.g., water well, cut, probe)
- Source — where the record came from (e.g., MOE[1], MTO, CA, Consultant, OGS geoscientist)
- Source id — the original id number
- Quality — an estimation of the reliability of the source data (high, medium or low)
- Quality 2 — as above, but with the continuously cored holes (definitive) separated out from other high-quality data

Picks Table

The Picks Table contains 28 272 records. This table presents a single snapshot view of the 3-D points used to generate each modelled surface from July 2009. The Picks Table is updated each time the model is changed to reflect the addition of new data or because of advances in the understanding of the subsurface stratigraphy. Some of the information is pulled from the Location Table (e.g., Quality, Type and Source). The Picks Table includes the following fields:

- X (NAD83) — the UTM easting co-ordinate in NAD83, Zone 17
- Y (NAD83) — the UTM northing co-ordinate in NAD83, Zone 17
- Z (masl) — the ground surface elevation in metres asl obtained from the provincial DEM
- Stratum — the code name of the hydrostratigraphic unit the pick corresponds to (i.e., GLAT, AF1, LD)

[1]The Ministry of the Environment (MOE) Water Well information contained in the subsurface database is offered to the User on an "as-is basis" and the MOE makes no guarantees, representations or warranties respecting the Well Information, either express or implied, arising by law or otherwise, including but not limited to effectiveness, completeness, accuracy or fitness for any purpose. The User hereby acknowledges that the Ministry of the Environment has advised the User that the Well Information may be incomplete or inaccurate.

- Sequence Number — the stratigraphic order of hydrostratigraphic unit where 1 is the youngest unit and 23 is the oldest unit
- Class — the simple aquifer/potential aquifer (AQF), aquitard (AQT) or bedrock (BED) classification of the hydrostratigraphic unit the pick corresponds to
- BHID — an internal 8-character MNDMF identification code used to link the tables in the subsurface database. Obtained from the Location Table.
- Quality — an estimation of the reliability of the source data (high, medium or low). This information is used to weight the picks so that the modelled surfaces better reflect the highest quality data. Obtained from the Location Table.
- Quality 2 — as above, but with the continuously cored holes ("Definitive") and off-trace picks ("Off-trace") separated out from other high-quality data
- Type — designates the method of excavation or type of record (e.g., water well, cut, probe). Obtained from the Location Table.
- Source — where the record came from (e.g., MOE[1], MTO, CA, Consultant, OGS geoscientist). Obtained from the Location Table.

Abbreviations used in this document:

API	application programming interface
AQF	aquifer
AQT	aquitard
asl	above sea level
BED	bedrock
CA	Conservation Authority
.csv	comma separated variable (comma-delimited) file
DEM	digital elevation model
.doc	Microsoft® Word document file
.jpeg, .jpg	lossy compressed colour image file developed by the Joint Photographic Experts Group
.kml	keyhole markup language file
.kmz	keyhole markup language files zipped
.mdb	Microsoft® Access® database file
MNDMF	Ministry of Northern Development, Mines and Forestry
MOE	Ministry of the Environment
MTO	Ministry of Transportation
NAD83	North American Datum 1983
.png	portable network graphics file
.pdf	portable document format file
UTM	Universal Transverse Mercator (co-ordinate system)
.xls	Microsoft® Excel® spreadsheet file

REFERENCES

Bajc, A.F. and Shirota, J. 2007. Three-dimensional mapping of surficial deposits in the Regional Municipality of Waterloo, southwestern Ontario; Ontario Geological Survey, Groundwater Resources Study 3, 41p.

Burt, A.K. 2007. Results of 2005 and 2006 Oro Moraine drilling program in the Barrie area, central Ontario; Ontario Geological Survey, Miscellaneous Release—Data 227.

Burt, A.K. and Russell, D.F. 2006. Results of 2004 Oro Moraine drilling program in the Barrie area, central Ontario; Ontario Geological Survey, Miscellaneous Release—Data 198.